


Integrated Water Infrastructure Vulnerability Assessment and Climate Resiliency Plan

TOWN OF CHARLTON &
TOWN OF SPENCER, MASSACHUSETTS

prepared by

FUSS & O'NEILL

JUNE 2019



Integrated Water Infrastructure Vulnerability Assessment and Climate Resiliency Plan

Charlton and Spencer, Massachusetts

June 2019

Prepared by

Fuss & O'Neill, Inc.

and

Town of Charlton and Town of Spencer, Massachusetts

Project No. 20170390.C51

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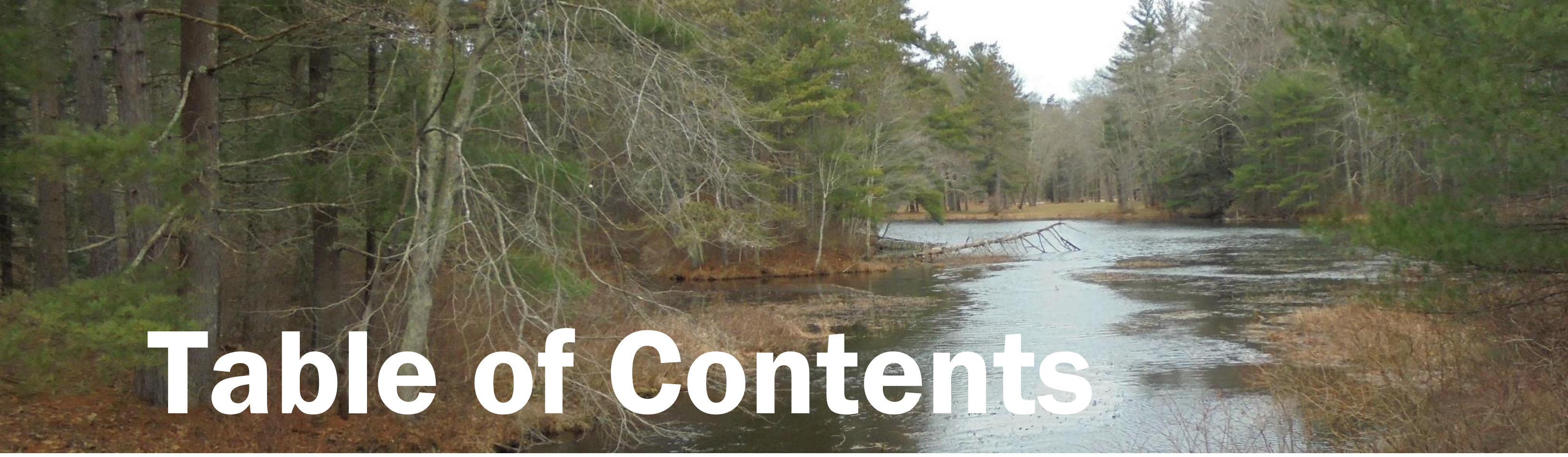
Document photos taken and provided by Fuss & O'Neill unless otherwise noted.

Financial assistance was provided by the Executive Office of Energy & Environmental Affairs (EEA) under the FY18 Municipal Vulnerability Preparedness (MVP) Grant Program. The MVP Action Grant offers financial resources to municipalities that are seeking to advance priority climate adaptation actions to address climate change impacts resulting from extreme weather, sea level rise, inland and coastal flooding, severe heat, and other climate impacts.



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1 Introduction

The municipalities of Charlton and Spencer, Massachusetts are taking steps to pro-actively address the flooding-related vulnerabilities of its water infrastructure – drinking water and wastewater facilities, stormwater infrastructure, road-stream crossings, and dams – and build resilience for changing climate conditions. Enhancing water infrastructure resilience through well-planned, cost-effective adaptation measures will make both communities more resilient to extreme precipitation events and flooding. This report describes an assessment of the vulnerability of water infrastructure in both communities and recommended adaptation measures to improve infrastructure and community resilience.

Water Infrastructure includes drinking water, wastewater, and stormwater infrastructure, as well as road-stream crossings (culverts and bridges), dams, and impoundments. Water infrastructure, like other public infrastructure, provides services and facilities that are essential to the public health, safety and well-being of a community. Storm events, flooding, and climate change has the potential to damage vulnerable water infrastructure and threaten public safety, particularly in the case of inadequate or outdated infrastructure.

1.1 Background

Extreme weather and natural and climate-related hazards are an increasing concern for the communities of Central Massachusetts. Climate changes, such as sea level rise, flooding, and extreme weather events are already affecting communities across Massachusetts. Participants at the Municipal Vulnerability Preparedness (MVP) Community Resilience Building workshops in April 2018 identified flooding as a high-priority challenge facing both communities. Moreover, the threat from flooding has been growing with the increasing frequency of major storm events that deliver large amounts of precipitation over a short time period. Climate projections for Massachusetts, developed by the University of Massachusetts, suggest that the frequency and intensity of extreme precipitation events will continue to trend upward, and the result will be an increased risk of flooding (MA Climate Change Clearinghouse, http://www.resilientma.org/). Adaptation, which means anticipating the adverse effects of climate change and taking appropriate action to prevent or minimize the damage they can cause, is necessary to avoid increasingly significant impacts.

1.2 Project Objectives and Scope

In 2018, following completion of the MVP planning process[1], the communities of Charlton and Spencer applied for and were awarded a FY 18 MVP Action Grant by the Massachusetts Executive Office of Energy

[1] The Municipal Vulnerability Preparedness (MVP) grant program provides support for cities and towns in Massachusetts to begin the process of planning for climate change resiliency and implementing priority projects. The state awards communities with funding to complete vulnerability assessments and develop action-oriented resiliency

and Environmental Affairs to conduct a detailed vulnerability assessment of water-related infrastructure (stormwater, culverts, dams, water, and wastewater) and develop planning recommendations to enhance flood resilience in both communities. The Towns, in collaboration with the MVP Program, commissioned this vulnerability assessment and adaptation planning process to:

- Identify water-related infrastructure at risk of flooding under present day and projected future climate change conditions
- Prioritize at-risk infrastructure
- Recommend site-specific and community-wide adaptation measures
- Engage municipal staff and the public in both communities.

The term "resiliency" or "resilience" is the ability to become strong, healthy, or successful again after something bad happens – the ability to spring back into action. **Flood resilience** refers to a community's ability to plan for, respond to, and recover from floods. It includes measures taken to reduce the vulnerability of communities to damages from flooding and to support long-term recovery after an extreme flood (EPA, 2014).

In addition to the MVP Planning process, this project also builds upon other related initiatives such as the recent update of the hazard mitigation plans in both communities by the Central Massachusetts Regional Planning Commission (CMRPC), previous grant-funded culvert assessment and replacement initiatives by the Town of Spencer, and municipal stormwater program implementation through the Central Massachusetts Regional Stormwater Coalition.

The project consisted of a series of technical assessments (review of relevant background studies and mapping and new field data collection and analysis) focused on each type of water infrastructure and associated climate change vulnerabilities. The project included a project steering committee, which consisted of municipal staff from both communities as well as representatives of the CMRPC. The results of the technical assessments, combined with input from the project steering committee, guided the development of an integrated climate resiliency plan. The plan includes prioritized adaptation recommendations and design concepts to support future implementation projects.

1.3 Purpose of the Plan

The purpose of this Integrated Climate Resiliency Plan is to:

- Enable the communities to be better prepared for and mitigate the impacts of extreme precipitation events and flooding
- Protect critical community infrastructure and the ability to deliver vital municipal services
- Promote resiliency measures that consider both infrastructure and natural system solutions, and encourage local decision-makers to think more strategically about using natural systems to enhance flood resiliency while also benefitting water quality and ecological health
- Identify recommended adaptation measures, costs, and funding sources (i.e., resiliency plan)
- Position the communities to obtain grant funding (through the MVP Action Grant program and other sources) to implement the plan recommendations.

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plans. Charlton and Spencer completed the MVP Planning process in 2018 to become certified as MVP communities and are eligible for MVP Action grant funding and other state funding opportunities.

1.4 Organization of the Document

- **Section 1 – Introduction** describes the project background, objectives, scope and how this plan is organized.
- **Section 2 – Plan Development Process** describes the process used to develop the plan, including the project partners and funding, Project Steering Committee, technical assessments, and community engagement process.
- **Section 3 – Flood Hazards and Vulnerable Infrastructure** summarizes the flooding issues in Charlton and Spencer, including the types and causes of flooding, areas susceptible to flooding, and vulnerable water-related infrastructure.
- **Section 4 – Vulnerability Assessments** describes the methods and results of vulnerability assessments performed for the major types of water infrastructure in both communities.
- **Section 5 – Adaptation Recommendations** describes recommended adaptation measures to address vulnerable infrastructure, including site-specific design concepts and policy and regulatory recommendations.
- **Section 6 – Funding Sources** identifies potential state and federal funding sources to augment municipal funding for implementing the plan recommendations.
- **Section 7 – References** contains a list of references cited in this document.
- **Appendices** the plan appendices include Town-specific summaries and links to technical reports documenting the technical assessments that serve as the basis for the plan recommendations.

2 Plan Development Process

2.1 Project Partners and Funding

In 2018, the Town of Charlton and the Town of Spencer received funding through the Municipal Vulnerability Preparedness (MVP) Grant Program, administered through the Massachusetts Executive Office of Energy and Environmental Affairs (EEA), for a joint project to conduct a climate change vulnerability assessment for the two Towns and develop an associated climate resiliency plan. Fuss & O'Neill, Inc. was retained by the Towns to lead the development of the assessments and resiliency plan. Key project partners include the municipalities, EEA, stakeholder groups, and interested citizens.

This project was funded by the inaugural round of MVP Action Grant Funding administered by the Massachusetts Executive Office of Energy and Environmental Affairs.

The climate resiliency plan addresses the major types of water infrastructure in both communities including water transportation systems (culverts and bridges), dams and natural impoundments, wastewater collection and treatment systems, water supply, and storm drainage systems. The project consisted of a series of technical assessments focused on each type of water infrastructure and associated climate change vulnerabilities.

The plan development process included review of relevant background information, studies, and mapping for both communities, as well as screening-level evaluations (using GIS data) and field data collection and analyses. The project included public participation and outreach and input from a project steering committee. The results of the technical assessments, combined with input from the public and project steering committee, guided the development of this integrated climate resiliency plan, which includes prioritized site-specific and town-wide recommendations, conceptual designs to support future implementation projects, and potential funding sources.

The plan builds upon recent and ongoing climate and flood resiliency efforts by the communities, as well as state and federal agencies, including:

- Town of Charlton MVP Planning Process and Community Resilience Building Workshop
- Town of Spencer MVP Planning Process and Community Resilience Building Workshop
- FEMA Flood Insurance Studies and hydrologic/hydraulic model information
- State Hazard Mitigation and Climate Adaptation Plan
- Local Hazard Mitigation Plan Updates (Central Massachusetts Regional Planning Commission - CMRPC)
- Spencer Culvert Assessment documents (Worcester Polytechnic Institute, 2015)
- Long Term Culvert Replacement Training Project (Division of Ecological Restoration, Massachusetts Department of Fish and Game, June 2016)

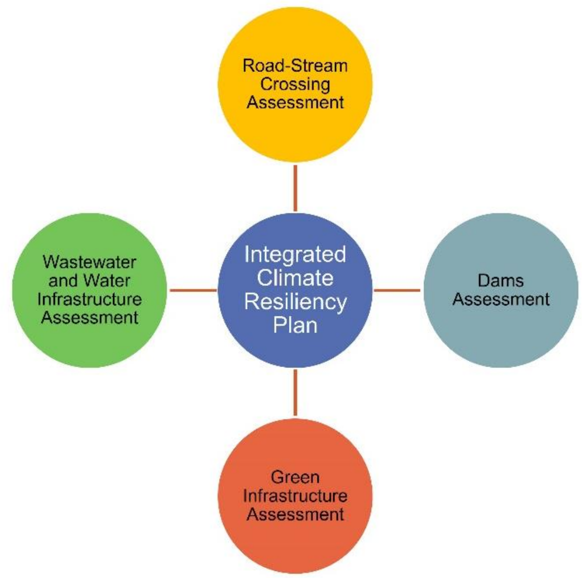
2.2 Project Steering Committee

A Project Steering Committee was formed to guide the plan development. The Steering Committee consisted of representative staff from multiple departments in both communities, including Planning, Public Works, Conservation, Emergency Services, and Town Administration.

Members of the Project Steering Committee attended regular meetings and provided review comments on draft deliverables. The Climate Resiliency plan reflects the combined efforts of the two Towns, government agencies, other stakeholders, and the Fuss & O'Neill project team. Members of the Project Steering Committee and other individuals involved in the plan development process are listed in the Acknowledgements section at the beginning of this document.

2.3 Technical Assessments

A series of technical assessments were conducted for each community to inform and guide the management plan recommendations. The assessments involved review of historic information and studies, screening-level evaluations using available GIS data to prioritize field efforts, and field data collection and analysis. The methods and results of the technical assessments are documented in separate technical memoranda. Electronic versions of the technical memoranda can be accessed at the links provided in the plan appendices.



- **Road-Stream Crossing Assessment:** Mapped road-stream crossings (i.e., culverts and bridges) in both communities were assessed to identify crossings that are vulnerable to flood hazards under present and projected future climate conditions, and to prioritize structures for upgrade or replacement given limited financial resources and aging transportation infrastructure. The assessments involved a combination of desktop assessment, field data collection, and prioritization/ranking and considered multiple factors – hydraulic capacity, structural condition, geomorphic vulnerability, aquatic organism passage, impacts on transportation and emergency services and other flooding impacts, and climate change impacts including projections of future extreme precipitation and streamflow. The assessment and prioritization approach was adapted from methods used by MassDOT and other transportation agencies in the Northeast and stream crossing survey methods developed by the North Atlantic Aquatic Connectivity Collaborative (NAACC).

- **Dams Assessment:** Existing dams in Charlton and Spencer were assessed and prioritized based on existing and future climate change flood risk, including upstream flood risk and downstream flood risk in the event of failure. Limited visual condition assessments were performed of the highest-priority dams, and recommendations were developed for each assessed dam to help decision-makers in each community prioritize the removal, repair or modification of dams to increase flood resiliency as well as improve aquatic habitat, river continuity, and fish passage.

- **Green Infrastructure Assessment:** A green infrastructure assessment was performed for each Town to identify green infrastructure (GI) and low impact development (LID) retrofit opportunities in both communities that would increase flood resiliency by reducing runoff volumes and peak flows and improve or protect water quality. Opportunities to implement GI/LID were assessed for Town-owned properties selected based on a desktop screening-level evaluation which identified areas within each Town with the highest feasibility for and potential benefits from GI/LID retrofits. The lists of potential sites were further refined based on input from the Towns to select sites for field inventories. Site-specific concept designs were developed for the ten most promising green infrastructure retrofit opportunities.

- **Water and Wastewater Infrastructure Assessment:** Existing water and wastewater infrastructure was evaluated for vulnerabilities associated with inland flooding and climate change impacts. The assessment included wastewater collection systems in each Town, the Spencer wastewater treatment facility, public drinking water source wells, and water distribution systems in both communities.

2.4 Community Outreach

Public participation and outreach was conducted as part of the MVP Action Grant and resiliency planning process to increase public understanding of issues currently affecting the Towns and the potential future impacts associated with climate change, and to raise awareness of the recommendations resulting from the assessments and build support for implementation of the plan. The following community outreach activities occurred during the planning process.

Project Steering Committee Meetings

A series of meetings were held with the Project Steering Committee to provide local information and feedback on the vulnerability assessments and to guide the development of recommended adaptation measures. Steering Committee meetings and/or conference calls were held on the following dates:

- September 24, 2018
- November 5, 2018
- November 26, 2018
- December 10, 2018
- January 28, 2019
- February 25, 2019
- April 22, 2019

Community Meetings

Community meetings were held in each town at the conclusion of the project. The Charlton community meeting was held on June 18, 2019 during a regular meeting of the Board of Selectmen. The Spencer community meeting was held as a stand-alone public information meeting on June 19, 2019. The purpose of these meetings was to present a summary of the assessment findings and recommendations and to encourage comments and questions from the public.

3 Flood Hazards and Water Infrastructure

3.1 Flooding in Charlton and Spencer

Types of Flooding

Riverine flooding is the most common type of flooding in low-lying areas of Charlton and Spencer. Riverine flooding occurs when rivers or streams overflow their banks and flow into the adjacent floodplain. Hazards associated with riverine flooding include both flood inundation of developed areas (roads, homes, businesses, etc.) and riverine erosion, including erosional and depositional processes. Riverine erosion can affect structures located both inside and outside the regulatory floodplain. The recurrence interval of a flood is defined as the average time interval, in years, expected to take place between the occurrence of a flood of a particular magnitude to an equal or larger flood. Flood magnitude increases with increasing recurrence interval (USGS, n.d.).

> The communities of Central Massachusetts are susceptible to the impacts of flooding caused by hurricanes, nor'easters, and severe rainstorms or thunderstorms. Charlton and Spencer have experienced historical and recent flooding that has resulted in roadway flooding, stream bank erosion, washout of roads, damages to and failure of dams, and flooding of properties and structures.

Drainage-related flooding is another common type of localized flooding, more likely to occur in developed areas such as downtown Spencer, the village areas of Charlton, and along transportation routes in both communities. It occurs as a result of drainage problems related to outdated or undersized storm drainage systems. Urbanization contributes to flooding by increasing impermeable surfaces, increasing the speed of drainage collection, and reducing the carrying capacity of the land, all of which can overwhelm storm drainage collection systems. Poorly draining soils, steep topography, and development can exacerbate localized drainage problems and drainage-related flooding.

Dam failure or breach can result from natural or human-induced events or some combination of the two. Failures due to natural events, such as prolonged periods of rainfall and flooding, can result in overtopping, which is the most common cause of dam failure. Overtopping occurs when a dam's spillway capacity is exceeded and portions of the dam, which are not designed to convey flow, begin to pass water, erode away and ultimately fail. Other causes of dam failure include design flaws, foundation failure, internal soil erosion, inadequate maintenance or operational failure. Dam failure or breach can result in sudden downstream flooding (i.e., flash flooding) and significant damages to infrastructure and property. In Charlton and Spencer, dam failure would lead to some of the most extreme damage, but is less likely to occur than riverine or drainage-related flooding (CMRPC, Charlton Local Hazard Mitigation Team, 2019; CMRPC, Spencer Local Hazard Mitigation Team, 2019).

Factors Contributing to Flooding

Several factors contribute to flooding in Charlton and Spencer, and more broadly, in Central Massachusetts. Historical development resulted in the filling of wetlands, floodplains, and floodways, which has reduced natural flood storage and placed development in flood-prone areas. Many of the streams in the region, as is common in New England, have also been physically modified (i.e., moved, straightened, hardened), which can increase riverine erosion hazards in certain areas. Development of the landscape with roads, parking lots, and buildings – impervious surfaces that prevent rainfall from infiltrating into the ground naturally – has increased the amount of storm runoff. Stormwater drainage infrastructure in developed areas also conveys runoff quickly to rivers and streams. Undersized bridges and culverts have also contributed to flooding and erosion. Dams in the county create flood hazards by backing up water during major floods and by releasing very large quantities of flow, sediment, and debris in the event of a sudden failure.

History of Flooding in Worcester County

Flooding and related events have caused significant damage in Worcester County, including Charlton and Spencer. Severe flooding in Worcester County generally occurs as a result of hurricanes or melting snows and spring rains, with more localized flooding caused by summer thunderstorms (FEMA, Revised 2014). **Figure 3-1** illustrates annual peak streamflow at four U.S. Geological Survey stream gage locations near Charlton and Spencer for the period 1961-2017, highlighting some of the major flooding events that have occurred in the area. Some of the more notable flooding events in the region include:

- **August - September 1954:** Hurricanes Carol and Edna reached Massachusetts as categories 3 and 1, respectively. Hurricane Carol dropped upwards of six inches of rain in central Massachusetts – Hurricane Edna arrived less than two weeks later, dropping an additional six inches of rain. These two heavy rainfall events so close together caused significant flooding across the state, including Worcester County (Massachusetts Office of Coastal Zone Management, n.d.).

- **August 1955:** Both Hurricanes Connie and Diane reached Massachusetts as tropical storms and caused heavy rainfall. In Charlton, 20 inches of rain fell over a five-day period, flooding Cady Brook and causing the failure of Glen Echo Dam and several smaller dams. In Spencer, 15 inches of rain fell over a two-day period, causing flooding of Muzzy Pond and a near overtopping of Muzzy Pond Dam (FEMA, Revised 2014).

- **August - September 1960:** Hurricane Donna hit Massachusetts as a tropical storm, leading to heavy rainfall and significant flooding across the state. In Worcester, almost five inches of rain were recorded in a single day at a USGS precipitation gage (USGS, n.d.).

- **March - April 1987:** Two spring storms produced rainfall that led to record snowmelt in Massachusetts, New Hampshire, and Maine. Over a nine-day period, more than ten inches of rain fell in Worcester. This heavy rainfall, combined with melting snow, flooded rivers and waterbodies and caused one of the worst floods in the states up to that point in history (National Oceanic and Atmospheric Administration, n.d.).

- **August 1991:** Hurricane Bob was classified as a category 2 when it reached Massachusetts, causing strong winds and heavy rains, leading to flooding across the state, including Worcester County. The significant damage it caused led it to be one of the most expensive hurricanes to ever hit Massachusetts.

- **September 1999:** Hurricane Floyd was a tropical storm by the time it hit Massachusetts. It dropped over four inches of rain in Worcester according to a USGS precipitation gage in the city (USGS, n.d.).

- **March 2010:** A FEMA Major Disaster Declaration was issued on March 29, 2010 in response to a severe storm and flooding in Massachusetts. Almost four inches of rain over a three day period at the beginning of March, while over four inches fell over a two-day period at the end of March (FEMA, n.d.).

- **August 2011:** Hurricane Irene was classified as a tropical storm when it reached Massachusetts. Over 5.5 inches of rain fell during a four-day period at the end of March.

- **October-November 2012:** Hurricane Sandy reached Massachusetts as "Superstorm Sandy," causing strong winds and heavy rainfall across Massachusetts. The USGS precipitation gage at Worcester measured almost two inches of rainfall over a two-day period (USGS, n.d.).

- **October 2016:** In Worcester and surrounding communities, over four inches of rain fell in less than a 24-hour period, flooding streets (USGS, n.d.).

- **July 2018:** A flash flood resulted from more than four inches of rain in parts Worcester and surrounding communities, flooding streets with up to three feet of water in some areas and submerging vehicles (National Weather Service, n.d.).

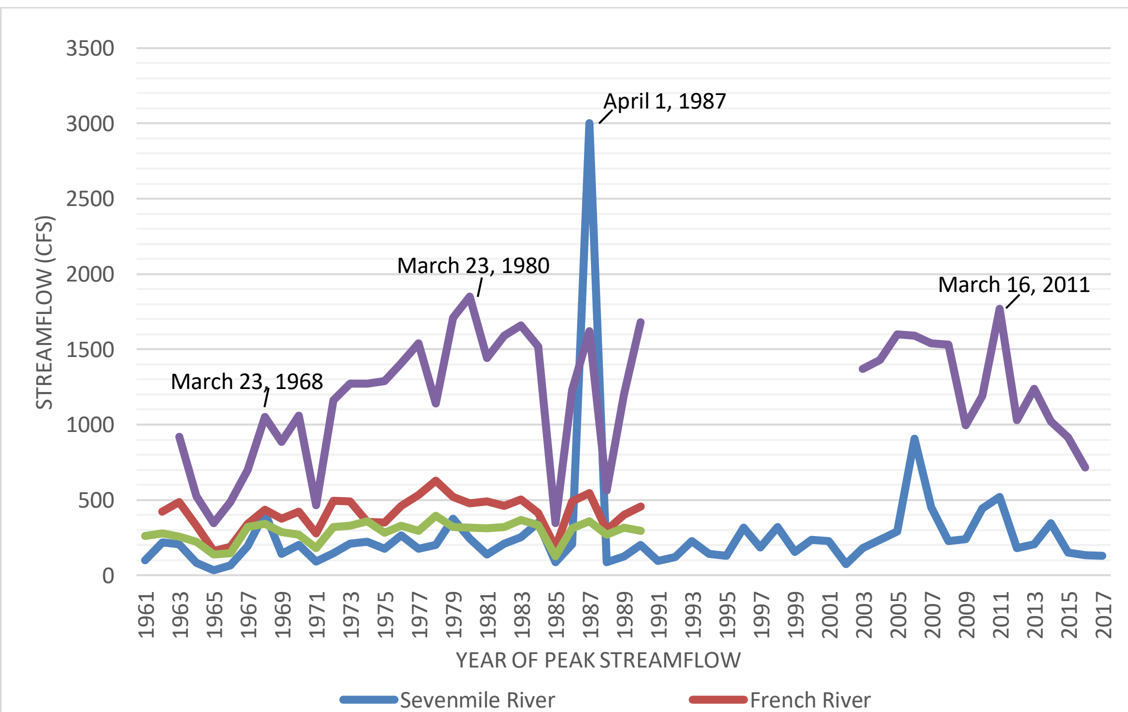


Figure 3-1. Plot of annual peak streamflow at four USGS stream gages near Charlton and Spencer.

Flooding and Climate Change

The risk of flooding and flood-related impacts are likely to intensify with a changing climate, including more severe and frequent rainfall events. Both mean and extreme precipitation in the Northeast region has increased during the last century, with the highest number of extreme events occurring over the last decade. Continued increases in frequency and intensity of extreme precipitation events are projected. According to the Fourth National Climate Assessment, "Moderate flooding events are expected to become more frequent in most of the Northeast during the 21st century because of more intense precipitation related to climate change" (Dupigny-Giroux, et al., 2018).

> In Massachusetts, observed increases in rainfall and the intensity and frequency of extreme precipitation events are expected to continue with changing climate conditions. Given current climate change projections, flooding and flood-related impacts are likely to intensify.

Currently, Massachusetts receives an average of 47 inches of rainfall per year. By mid-century, this is expected to increase by 1-6 inches, and by the end of the century, it is expected to increase 1.2-7.3 inches. Driving this increase in average annual precipitation is an increase in the frequency and intensity of extreme rainfall events. From 1958-2010, there was a 70% increase in precipitation during heavy rainfall events in the Northeast – this is only expected to rise as climate change progresses (Melillo, Richmond, T.C., & Yohe, G.W., 2014). More frequent and intense rainfall will lead to higher incidence of flooding in communities like Charlton and Spencer, as this rainfall can overwhelm the soil's ability to absorb water, increase the burden on the stormwater system, and flood waterbodies. The risk of riverine and drainage-related flooding is expected to increase, and bridges, roads, dams, and other infrastructure will be more susceptible to flood damages.

Given this trend, the communities of Charlton and Spencer face an increasing risk of flooding and storm-related damages as large storms and floods become more common. In addition to climate change, some parts of the communities are susceptible to future development pressure that, if not appropriately controlled, could increase floodplain encroachments, reduce the natural water-absorbing capacity of the land, increase impervious surfaces and stormwater runoff, and worsen flooding impacts.

Existing Flood Mitigation and Resiliency Measures

Flood Control Structures

As a result of the 1955 flood, the U.S. Army Corps of Engineers constructed numerous flood control structures (dams, dikes, channel improvements, etc.) in the region, including Buffumville Dam on the Little River in Charlton and several structures in the Town of Leicester, which provide flood protection for the Sevenmile River in Spencer. The Army Corps maintains and operates these and other flood control structures in the region to mitigate riverine flooding.

National Flood Insurance Program (NFIP)

Both Charlton and Spencer participate in the National Flood Insurance Program (NFIP), established by Congress in 1968 to provide flood insurance to property owners in participating communities. This program is a direct agreement between the federal government and the local community that flood insurance will be available to residents in exchange for the community's compliance with minimum floodplain management requirements such as the adoption of a floodplain management or flood damage prevention ordinance. In order for property owners to purchase flood insurance through the NFIP, their community must be in good participant standing in the NFIP. Communities participating in the NFIP must:

- Adopt the FIRMs as an overlay regulatory district or through another enforceable measure
- Require that all new construction or substantial improvement to existing structures in the Special Flood Hazard Area will be compliant with the construction standards of the NFIP and State building code, which is implemented at the local level by municipal building officials
- Require additional design techniques to minimize flood damage for structures being built in high hazard areas, such as floodways or velocity zones.

3.2 Areas Vulnerable to Flooding

To implement floodplain management programs and for flood insurance rates, federal and state agencies and local communities use flood events of a magnitude which are expected to be equaled or exceeded once, on the average, during any 10-, 50-, 100-, or 500-year period (recurrence interval). These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year (FEMA, Revised 2014). For example, a 100-year flood is not a flood that occurs every 100 years. In fact, the 100-year flood has a 26-percent chance of occurring during a typical 30-year mortgage (USGS, 2010). **Figure 3-2** depicts the 1-percent and 0.2-percent annual chance Special Flood Hazard Areas (FEMA flood zones) in Charlton and Spencer based on the current FEMA Flood Insurance Rate Maps.[2]

The Towns of Charlton and Spencer are located within three major watersheds: the Chicopee River, the French River, and the Quinebaug River watersheds. The major watershed boundaries in Charlton and Spencer are shown in **Figure 3-2.** The western half of Charlton lies within the Quinebaug River watershed, and the eastern half of the town is within the French River watershed. The major riverine flood hazard areas in Charlton are generally located along the mainstream and tributaries of the Quinebaug River and Little River. Approximately 3/4 of the land area in Spencer falls within the Chicopee River watershed and 1/4 in the French River watershed, with only a small portion in the Quinebaug River watershed. In Spencer, the major riverine flood hazard areas are located along the mainstream and tributaries of the Sevenmile and Upper French Rivers. Flooding also occurs at isolated locations in both communities due to undersized or outdated drainage infrastructure.

Documented locations of flooding in both communities were identified based on information obtained from the FEMA Flood Insurance Study report for Worcester County, the updated local hazard mitigation plans, input from the Project Steering Committee, municipal staff, and residents. The table in **Appendix A** lists documented flooding locations including specific sites such as individual road-stream crossings, bridges, streets, etc., as well as more generalized areas of flooding or erosion, such as entire neighborhoods or stream reaches.

[2] FEMA is working with USGS and other federal, state, and local partners to identify flood risk and help reduce that risk through the Risk Mapping, Assessment and Planning (Risk MAP) program. Risk MAP is designed to help increase the purchase of flood insurance and increase the public's awareness of flood prone structures and potential mitigation measures, including update of FEMA flood zone mapping. Under this program, updated Preliminary Flood Insurance Rate Maps (FIRMs) and an updated Flood Insurance Study (FIS) report are scheduled to be released to community officials for Worcester County by mid-2019 (FEMA, 2019).

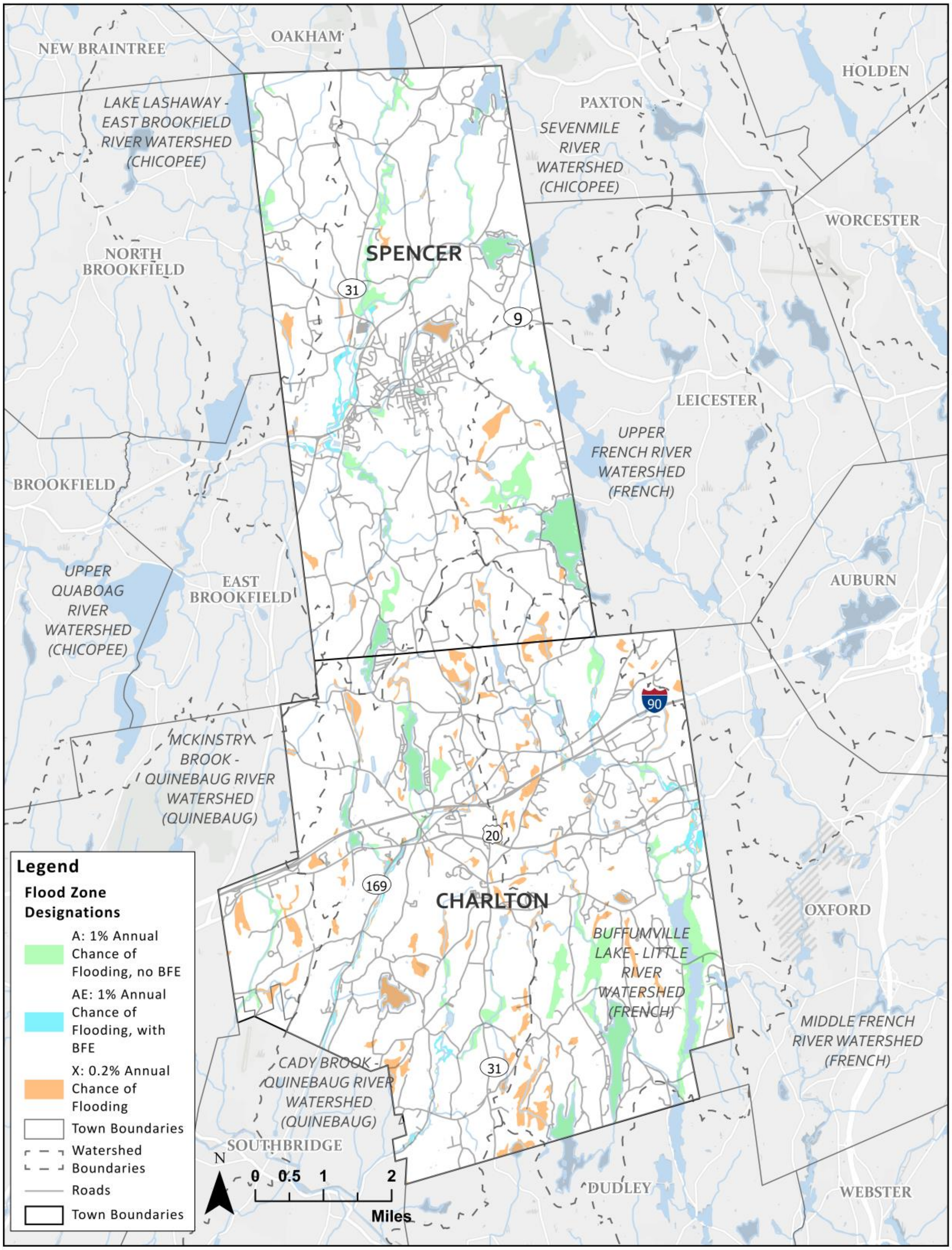


Figure 3-2. Special Flood Hazard Areas in Charlton and Spencer.

The CMRPC and the respective Hazard Mitigation Teams from both communities also identified the following vulnerable areas based on previous known occurrences of flooding:

- **Charlton:** North Sturbridge Road, Brookfield Road, Gould Road, City Depot Road, Stafford Street, Wilson Lane, and School House Road (CMRPC, Charlton Local Hazard Mitigation Team, 2019).

- **Spencer:** Cherry Street buried brook, the North Spencer Road Bridge over the Sevenmile River below Abbey Pond Dam #3, Meadow Road along Sevenmile River, Turkey Hill Brook downstream of Thompson Pond Dam, and north and west of the Stiles Reservoir near GH Wilson Road and Clark Road (CMRPC, Spencer Local Hazard Mitigation Team, 2019).

More detailed information on these flood-prone areas can be found in the table in **Appendix A.**

3.3 Water Infrastructure

This section provides an overview of the water-related infrastructure in Charlton and Spencer that was the focus of the vulnerability assessments and climate adaptation planning. **Section 4** describes an assessment of each type of water infrastructure in both communities to further evaluate the vulnerability of specific sites and facilities to flooding and flood-related impacts.

Road-Stream Crossings

There are an estimated 300+ road-stream crossings in Charlton and Spencer, which include crossings of mapped "blue-line" perennial and intermittent streams (**Figure 3-3**). Numerous other crossings of unmapped streams likely exist throughout both towns, as well as a significant number of smaller crossings that convey stormwater drainage beneath roads. Crossings of unmapped streams and drainage crossings were not included in the assessment as they typically pose a smaller risk of significant flooding than crossings that convey flowing streams. As is the case with much of the transportation infrastructure in New England, the road-stream crossings in both communities include a variety of culverts and bridges, many of which are known or believed to be undersized, in poor structural condition, and susceptible to damages during flood events.

Dams

There are 51 state-registered dams in Charlton and Spencer (**Figure 3-4**). Other unregistered or undocumented dams are also likely present in both communities. Aside from the few dams that were built for flood control purposes in the late 1950s, many of these are relatively small dams built to power industrial mills of the 17th and 18th centuries, are no longer used for their original purpose, and are in poor or deteriorating condition. Some of these dams could pose upstream flooding hazards by backing up water during floods. Dams also present a hazard to downstream areas in the event of a breach or failure, which can result from aging infrastructure, insufficient maintenance and changes in upstream flow regimes. (Note that FEMA flood hazard mapping does not account for areas that would be impacted in the event of a dam failure.) Dam failure can release large quantities of flow, sediment (sometimes contaminated), and debris and is therefore a threat to property, ecosystems, and public safety. Dams have also fragmented the riverine systems in the watershed, preventing the movement of fish and other aquatic life to feed, spawn, or migrate past the dams.

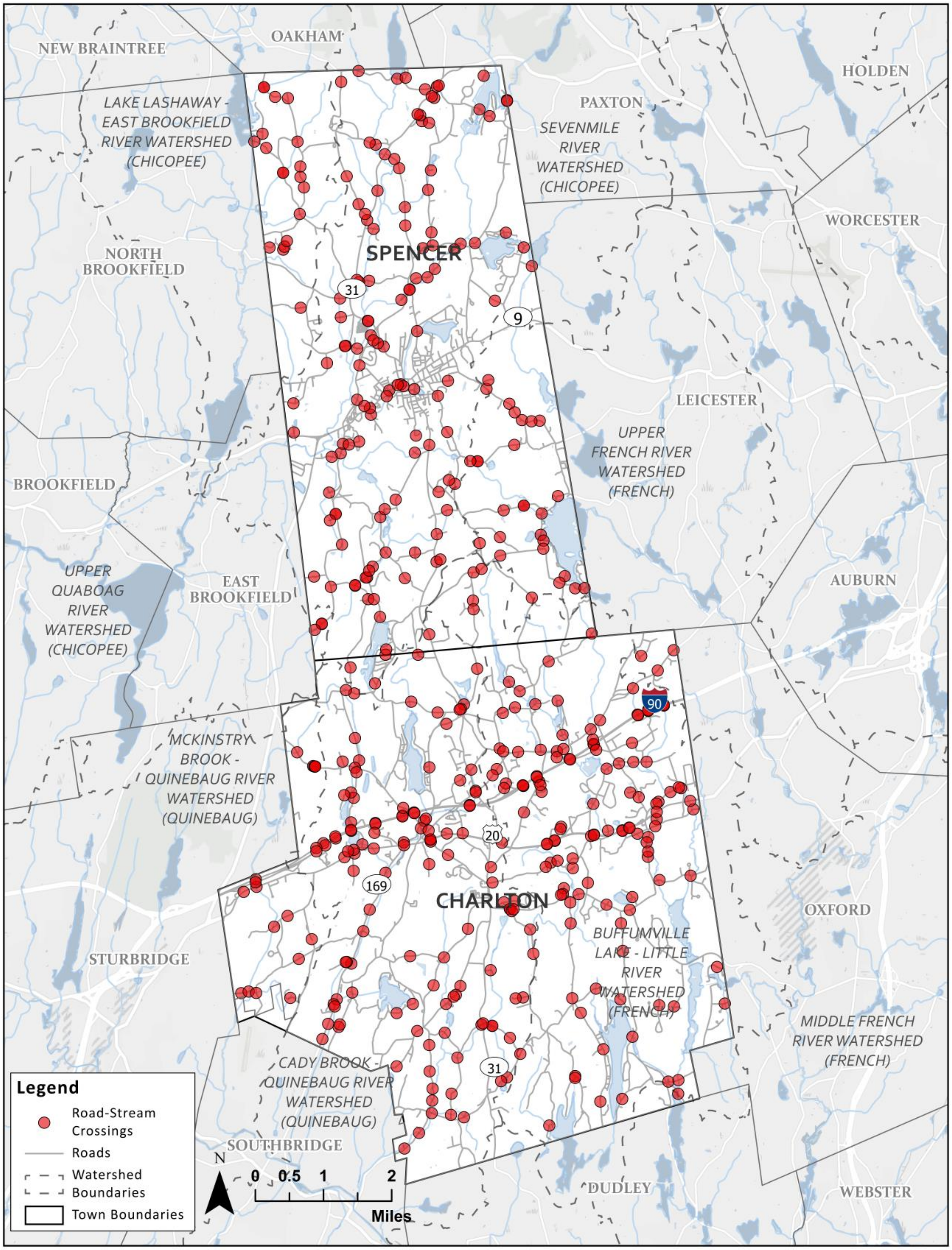


Figure 3-3. Road-stream crossings in Charlton and Spencer.

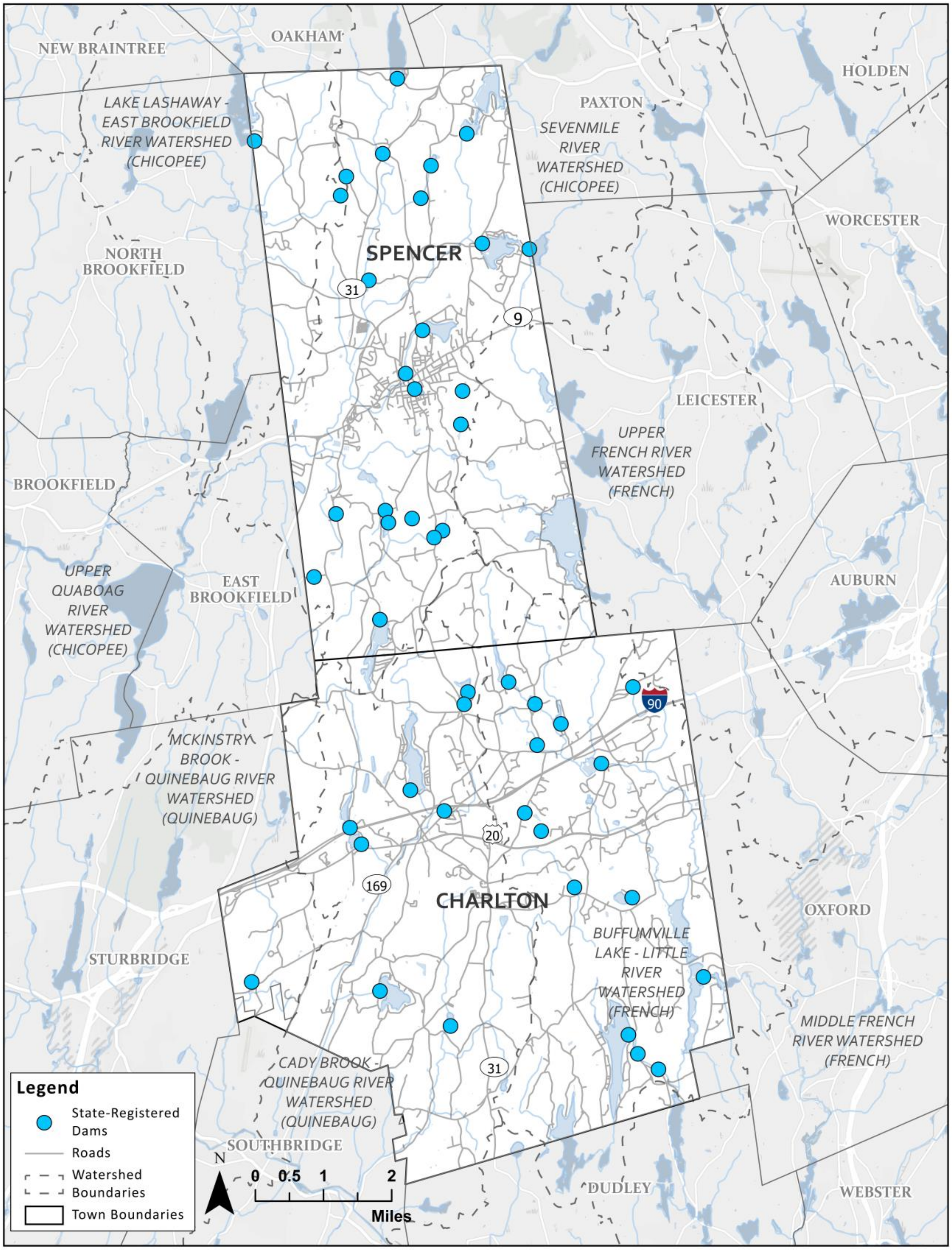


Figure 3-4. State-registered dams in Charlton and Spencer.

Water and Wastewater Infrastructure

Water and wastewater infrastructure – distribution and collection systems and related pumping and treatment facilities – can be impacted by inundation flooding, rising groundwater elevations, and washout of transportation infrastructure. Service interruptions of water and wastewater facilities could significantly affect both communities in terms of public health and the environment.

Charlton

The Town of Charlton's water system (**Figure 3-5**) is supplied from Sturbridge and includes a water distribution system that services a portion of the municipality including along Route 20, Route 169 to the south and west, South Sturbridge Road, Stafford Street, Hammond Road, Timber Valley Road and Northside Road in a loop with Route 20, and the interconnection with Sturbridge. The water system also has two storage tanks with a combined storage capacity of almost a million gallons to manage higher system demands and provide fire flows. Water distribution system infrastructure exists to the west of Northside Road, which was installed but not used due to a permit denial to transfer water from Oxford.

Charlton's wastewater system (**Figure 3-5**) includes a Wastewater Treatment Facility (WWTF) that is just south of Route 20 between Route 169 and Carpenter Hill Road. The plant includes Rotating Biological Contactors (RBC's), clarification as well as disinfection prior to discharging to Cady Brook. The collection system includes gravity sewer and force main throughout Town that totals almost 20 miles. Specific areas include the neighborhoods around Glen Echo Lake (4 pump stations in this area), and the area just north of the Massachusetts Turnpike near Stafford Street. The system is also south of Route 20 extending to the east near the existing schools in the area. The system also extends to the west along Route 20 ending adjacent to the Massachusetts Turnpike. The system also includes 10 wastewater pump stations.

Spencer

The Town of Spencer's water system (**Figure 3-6**) consists of two sources of supply – the Sevenmile River Wellfield and the Cranberry Wellfield. Each produces enough water to service the entire community. The Sevenmile River Wellfield is adjacent to the Water Treatment Plant on Meadow Road and just east of the Sevenmile River and the regulatory floodway. The Cranberry Wellfield is situated off South Spencer Road and just south of the existing Wastewater Treatment Facility. The distribution system's spine runs along Route 9 from the edge of East Brookfield through the town center and east to the Town of Leicester and Shaw Pond. There are also numerous distribution system feeds to the north and to the south from Route 9. Two water storage tanks, the Moose Hill Tank and the Highland Street Tank, provide additional supply for peak demands, emergency supply, and fire protection.

Spencer's wastewater collection system (**Figure 3-6**) primarily serves the central portion of the Town, including the downtown and surrounding areas. The system is predominantly gravity-fed, with only one (1) pump station on Meadow Street adjacent to Fourth Avenue. This pump station carries approximately 10 percent of the wastewater from the northern portion of Town to the Wastewater Treatment Facility, which is located off of Route 9 just to the east of the Podunk Turnpike.

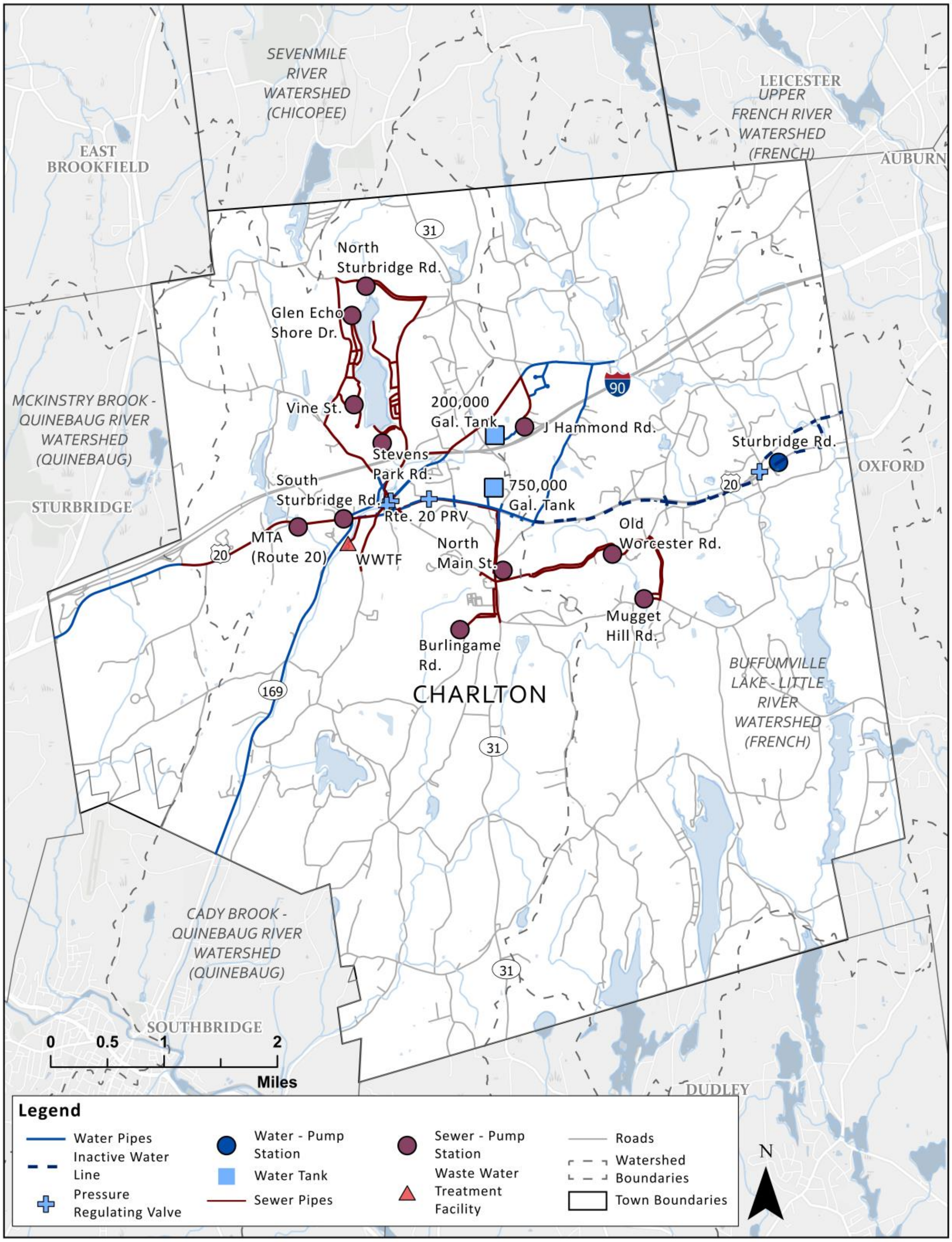


Figure 3-5: Water and wastewater infrastructure in the Town of Charlton.

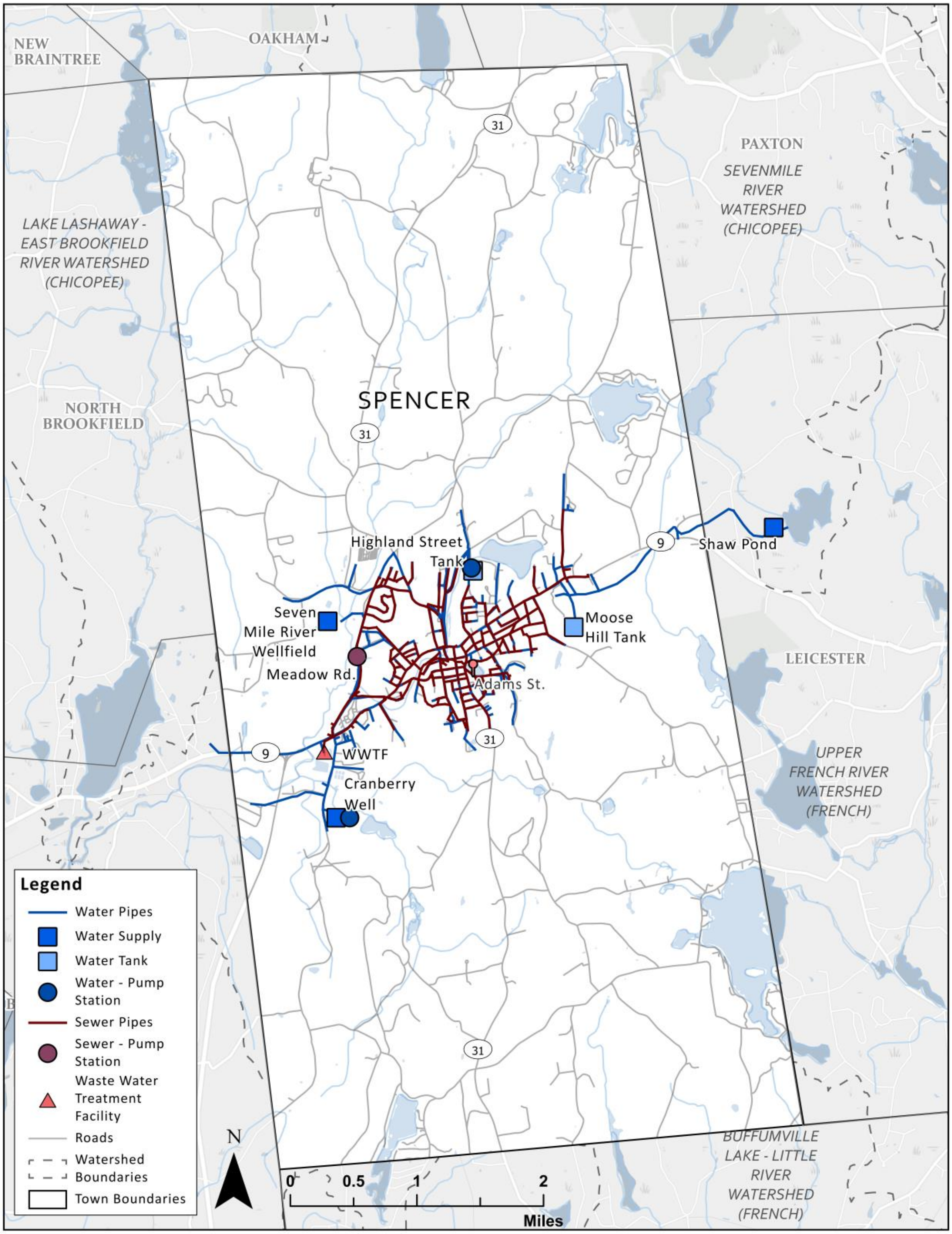


Figure 3-6: Water and wastewater infrastructure in the Town of Spencer.

Stormwater Infrastructure

Both communities are served by storm drainage systems (catch basins, manholes, storm drainage pipes, outfalls, etc.) that collect and convey runoff from public roads, parking lots, buildings, and other areas to nearby rivers, streams, lakes, ponds, and wetlands (**Figure 3-7, Figure 3-8**). Storm drainage infrastructure tends to be more prevalent in the developed town and village centers, in residential subdivisions, and along the major transportation corridors. Storm drainage infrastructure in both towns includes areas of older drainage systems with known or suspected capacity issues that can result in localized flooding during heavy rain events. Stormwater runoff from impervious surfaces contributes to both localized drainage-related flooding and riverine flooding. The use of green infrastructure practices throughout the watershed can help to infiltrate and slow runoff, which can mitigate localized flooding and help to reduce peak discharges in rivers and streams, as well as provide water quality and other community benefits.

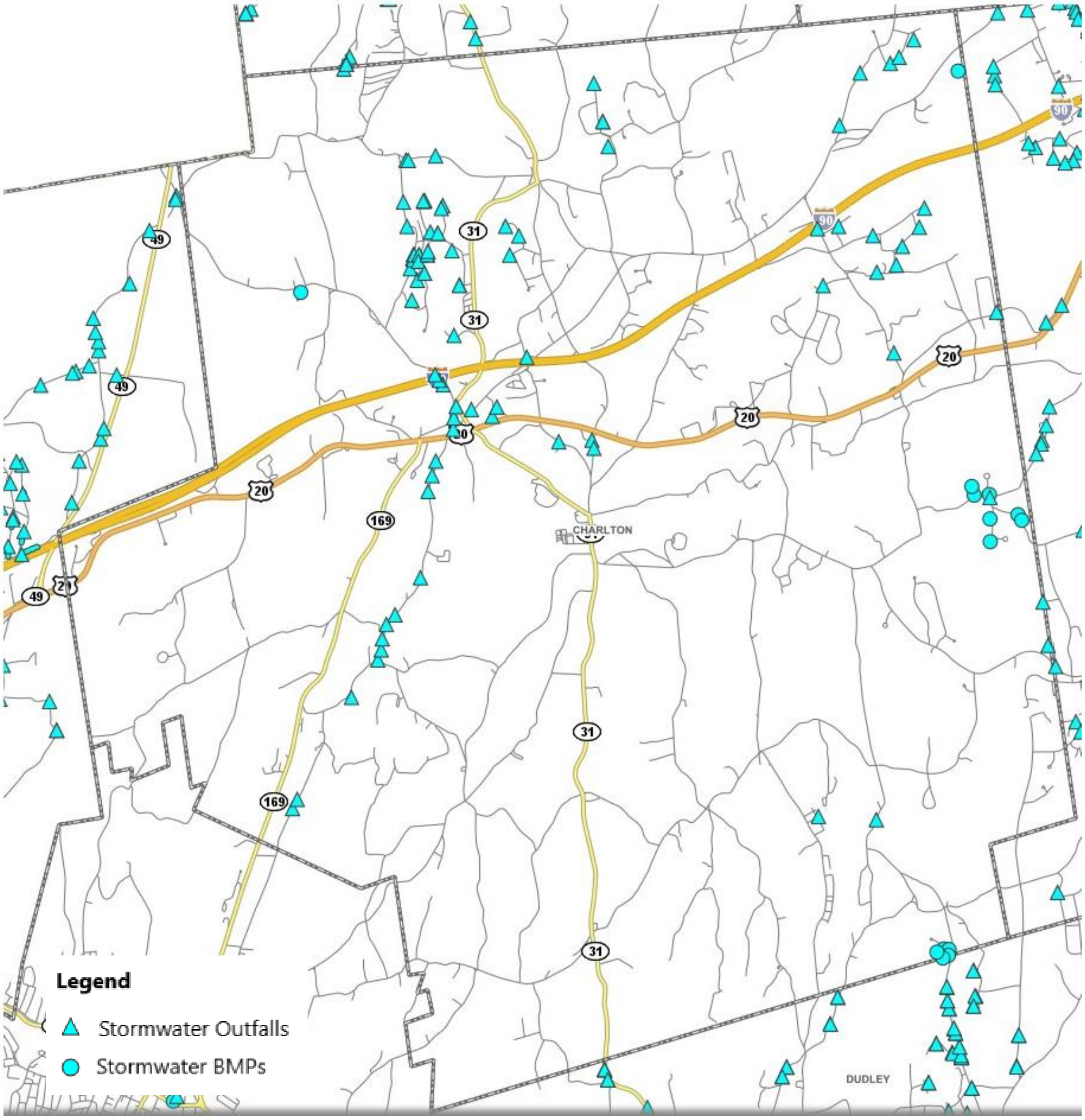


Figure 3-7: Stormwater infrastructure in the Town of Charlton.

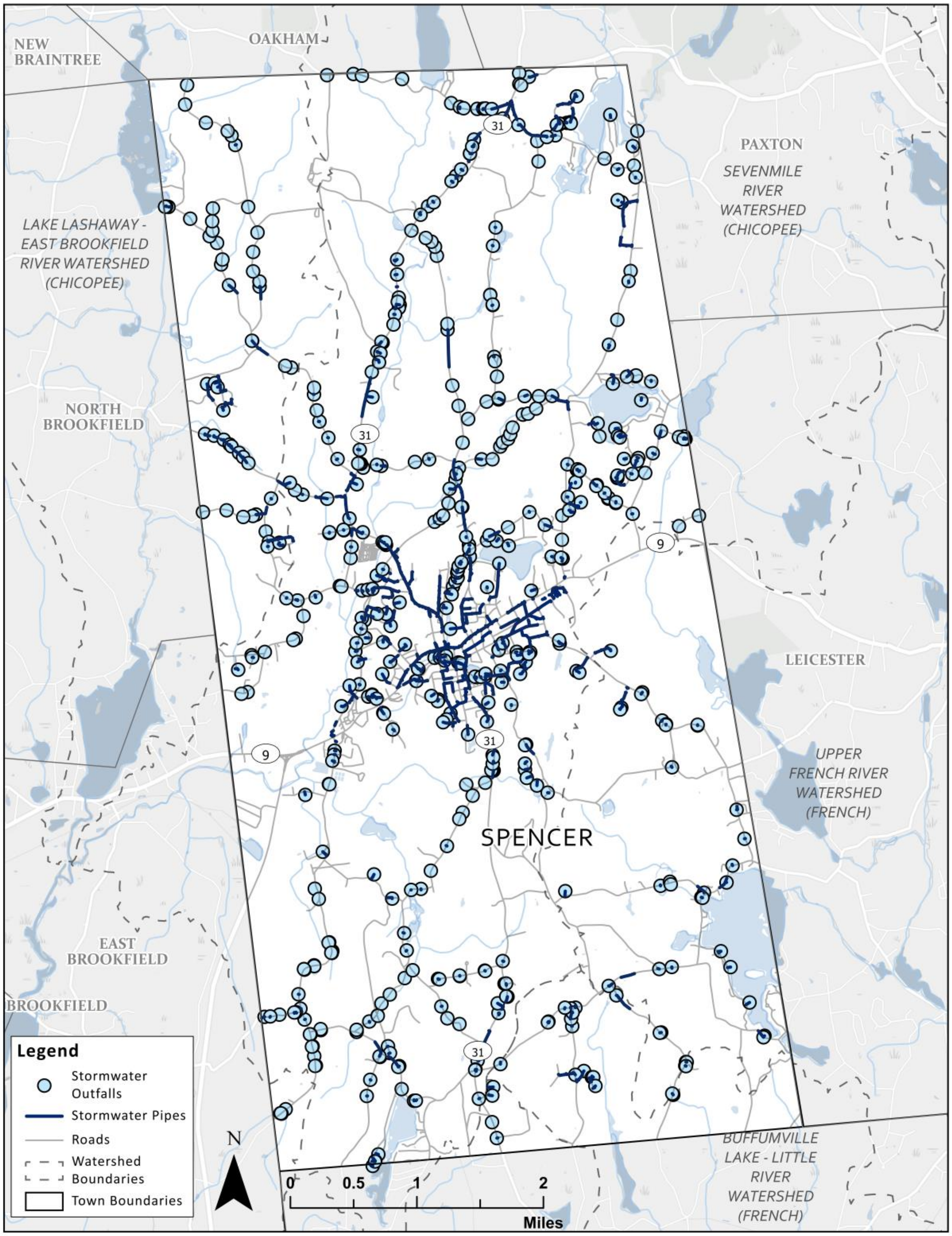


Figure 3-8: Stormwater infrastructure in the Town of Spencer.

4 Vulnerability Assessments

4.1 Road-Stream Crossings

Why are Roads Vulnerable?

Road-stream crossings (i.e., culverts and bridges) are an integral part of transportation infrastructure. Inadequate or undersized road-stream crossings can be infrastructure liabilities and flooding hazards for communities and can serve as barriers to the passage of fish and other aquatic organisms. Poorly designed and undersized crossings can increase flooding of upstream and adjacent areas or have significant impacts to the transportation system. Across the U.S., culvert failures cost communities millions of dollars every year in property and infrastructure damages (MADER, June 2012). Culverts can also serve as barriers to the passage of fish and other aquatic organisms along a river system, altering aquatic habitat and disrupting river and stream continuity.

Common Stream Crossing Problems

Undersized or Inadequate Crossings

Undersized or inadequate crossings can restrict natural streamflow during high flows, causing scour and erosion, backing up water and depositing sediment behind the crossing, creating higher flow velocity and erosion downstream, clogging, and washout. Crossings should be large enough to accommodate high flows and to pass fish and other wildlife.

Shallow Crossings

Shallow crossings have water depths that are too low for many organisms to move through, and the bottom may lack appropriate stream bed material. Crossings should have an open bottom or should be buried into the streambed. Natural substrate should be used within the crossing, it should match the upstream and downstream substrates, and it should resist displacement during floods.

Perched Crossings

Perched crossings are above the level of the stream bottom at the downstream end, restricting upstream passage by fish and other aquatic organisms and contributing to downstream bed scour. Crossings should be open-bottomed or embedded into the bottom of the stream channel to prevent perching.

As precipitation events become more intense and less predictable as a result of climate change, inadequate or undersized road-stream crossings throughout the Town of Charlton and the Town of Spencer are expected to pose a greater threat of failure; flooding damage to homes and businesses, transportation infrastructure, and utilities; and stream channel erosion.

Assessment Methods

Stream Crossing Field Surveys

Road-stream crossings were initially identified based on review of aerial imagery, flood mapping, and other local, county, or state-wide data layers. The Project Steering Committee provided additional information on locations of known culvert/bridge infrastructure where flooding was already a concern. The field assessment included all crossings Town-wide which could reasonably and safely be assessed (this excluded crossings of the Massachusetts Turnpike [Interstate 90] and State Route 20 that could not be accessed).

In total, 241 road-stream crossings throughout the two towns were assessed during the fall of 2018 via field surveys and followed-up with desktop vulnerability assessments (132 crossings in Charlton and 109 crossings in Spencer). As shown in **Figure 4-1**, the crossings span seven watersheds. The assessment is documented in a separate *Road-Stream Crossing Assessment Technical Memorandum* (Fuss & O'Neill, 2019a) (**Appendix B**).

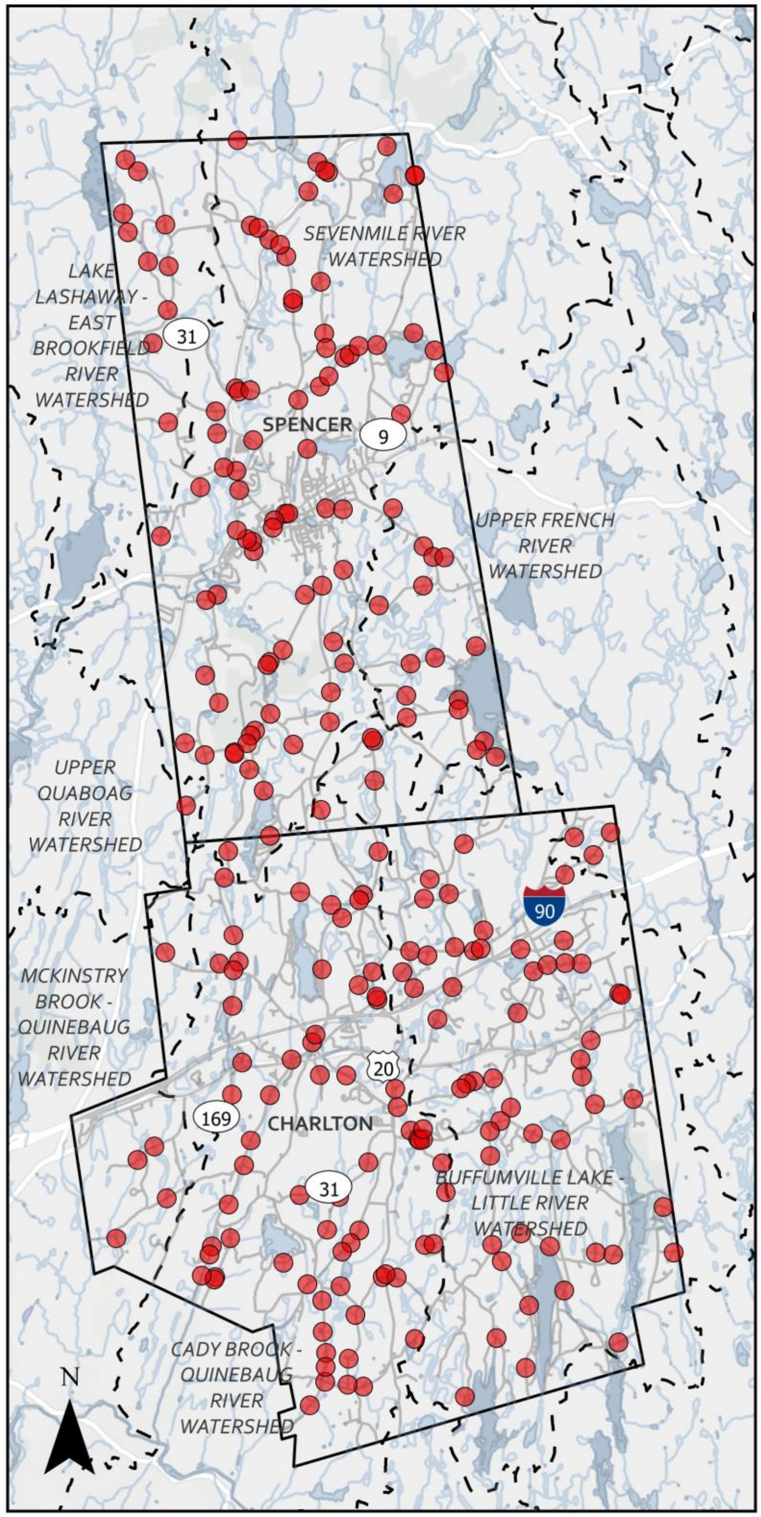


Figure 4-1. Road-stream crossings selected for assessment in the Town of Charlton and the Town of Spencer. Major watershed boundaries are indicated by dotted lines.

Road-stream crossing assessment procedures were adapted from the 2016 North Atlantic Aquatic Connectivity Collaborative (NAACC) stream crossing survey protocol for assessing aquatic connectivity, and also incorporated structural condition assessment protocols from the 2017 NAACC Culvert Condition

Assessment Manual, as well as collection of other field data for evaluating geomorphic vulnerability, hydraulic capacity, and potential flooding impacts to infrastructure and public services.

Assessment Findings

The major findings of the assessment are as follows:

- **An estimated 64% of the assessed stream crossings are hydraulically undersized relative to their ability to convey the 10-year peak flow. This number increases to 69% for expected future conditions under climate change. Figure 4-2** shows the percentage of existing and predicted future hydraulic capacity ratings of the assessed stream crossings. Hydraulic capacity rating reflects the largest recurrence interval peak discharge that a structure can convey without failing. Circular pipes and box culverts make up the majority of the hydraulically undersized stream crossings in both towns.

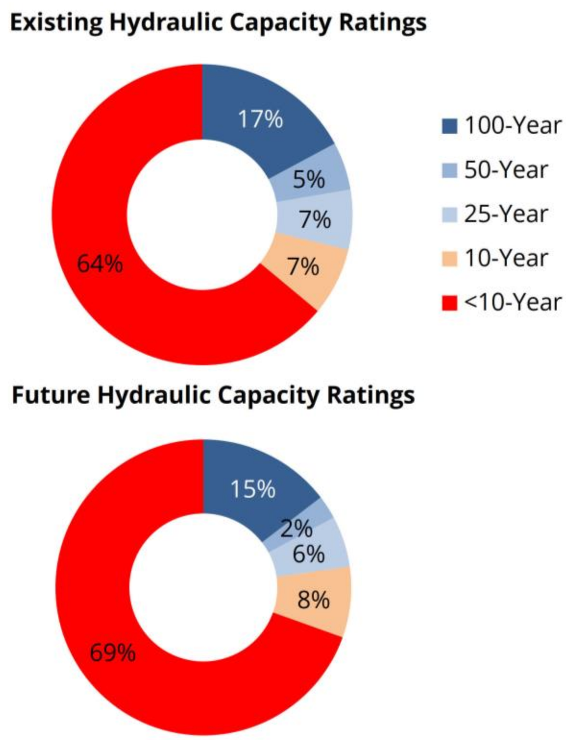


Figure 4-2. Percentage of assessed crossings by existing and future hydraulic capacity ratings.

- **33% of the assessed structures in the two communities have a high geomorphic vulnerability rating (Figure 4-3).** Geomorphic vulnerability of a culvert or bridge refers to the likelihood of potential impacts of the structure on channel stability based on consideration of the physical characteristics of the structure and stream channel. Crossings with the highest geomorphic risk include crossings on Mill Street, May Street, Gold Nugget Road, Marble Road, and Wire Village Road in Spencer and Route 169/Southbridge Road and Stafford Street in Charlton.

- **46% of the assessed structures were rated as critical relative to structural condition, while 52% were rated as either good or satisfactory (Figure 4-3).** Of the ten crossings that rated highest for structural risk based on structural condition and potential for flooding impacts, five are also among the top priority crossings overall. The crossings with the highest (most critical) structural condition ratings are clustered in the Spencer town center area.

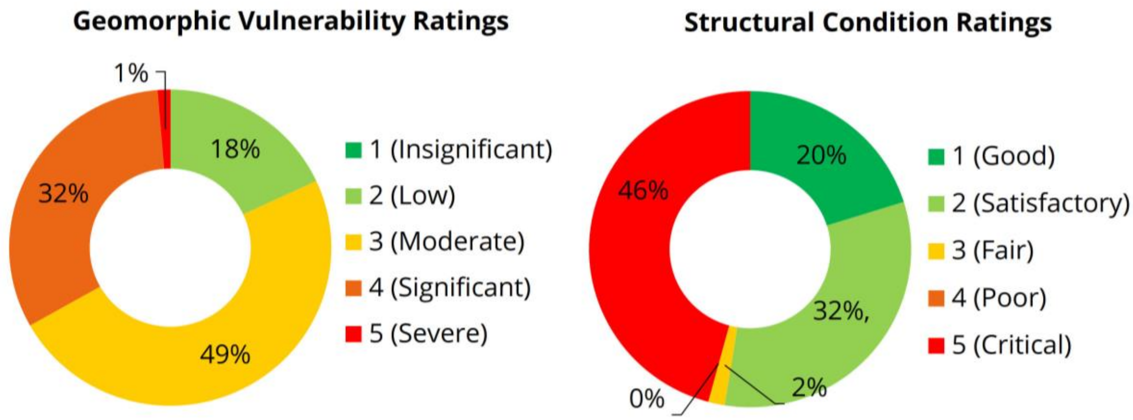


Figure 4-3. Percentage of assessed crossings by geomorphic vulnerability (left) and structural condition (right) ratings.

- **19% of stream crossings within the two towns provide for full passage of aquatic organisms (Figure 4-4).** The percentage of assessed structures that were identified as moderate to severe barriers (55%) to aquatic organism passage is consistent with other regional stream crossing assessments in New England. Bridges generally have the largest openings and provide the greatest continuity, while box culverts and circular pipes are the greatest barriers to aquatic organism passage. Among the 34 crossings with the highest potential AOP benefit scores—that is, crossings which are barriers to aquatic organism passage but which are also at locations where improved passage would have the greatest benefit—25 were also scored as high priority overall. The majority of the crossings with the highest AOP benefit scores are evenly split between the Sevenmile River, Buffumville Lake-Little River, and Cady Brook-Quinebaug River watersheds.

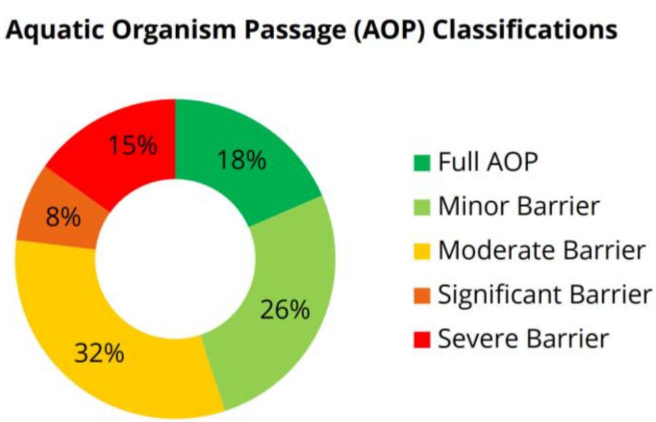


Figure 4-4. Percentage of assessed crossings by aquatic organism passage (AOP) classification.

- **The highest potential for transportation disruptions due to flooding was found on state roadways, with the highest impact crossings located on Route 169/Southbridge Road and Route 9.** The sites with the highest potential for flooding impacts were located in densely developed areas, and crossings in the Spencer town center area were the highest ranked overall for potential impacts.

- **21% of the assessed structures are rated as high priority for upgrade or replacement (Figure 4-5).** The priority ratings are based on the combined consideration of hydraulic capacity, structural condition, geomorphic vulnerability, aquatic organism passage, and flooding impact potential. 47% of the crossings are rated as intermediate priority, and 32% as low priority.

  The seven crossings with the highest overall scaled crossing priority values are all located within the Sevenmile River watershed, in the Town of Spencer. The Elm Street crossing of an unnamed tributary to the Sevenmile River and the Wire Village Road crossing of an unnamed tributary to Turkey Hill Brook were the two highest priority crossings overall. Both of these crossings are also among the highest priorities for aquatic organism passage.

  Downstream of the Elm Street crossing, three additional crossings of the same tributary at Water Street, Mill Street, and Valley Street are the third, fourth, and sixth highest priority crossings, respectively. Crossings of unnamed streams at May Street and Gold Nugget Road are also among the top seven crossings.

  The next highest ranked cluster of crossings consists of 8 crossings all receiving a score of 0.69. These crossings are spread between the Sevenmile River, Cady Brook-Quinebaug River, and Upper French River watersheds, and split between Charlton and Spencer.

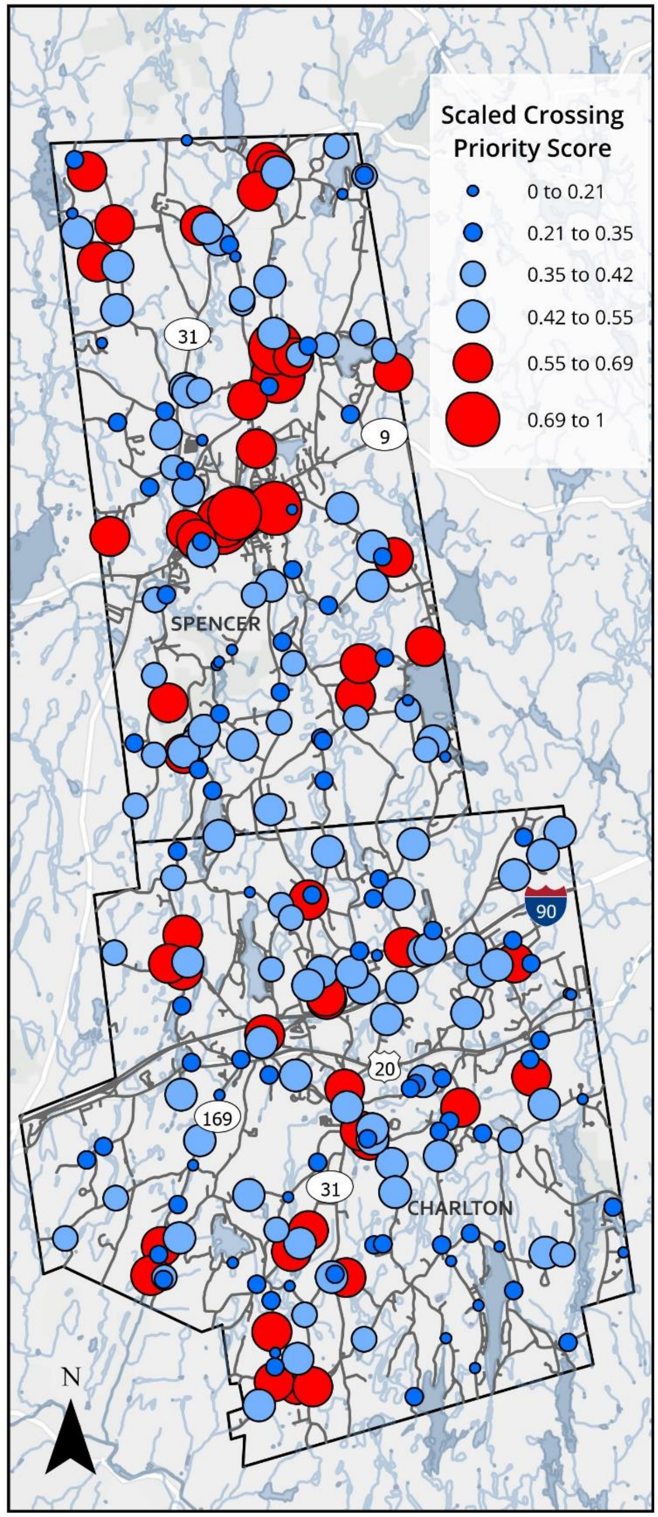


Figure 4-5. Spatial distribution of scaled crossing priority scores for all assessed crossings. Red dots indicate high priority crossings; light blue dots indicate medium priority crossings; dark blue dots indicate low priority crossings.

4.2 Dams and Impoundments

Why are Dams and Impoundments Vulnerable?

Many of the dams in Charlton and Spencer were built to power industrial mills and are now obsolete structures that are older than their designed lifespan and are insufficiently maintained. Dams present a hazard to downstream areas in the event of a breach or failure, which can release large quantities of flow, sediment, and debris and is therefore a threat to property, ecosystems, and public safety. More frequent and intense storms will put greater stress on this aging infrastructure, increasing the likelihood of potential failure and downstream flood-related impacts. In addition to flooding hazards and financial liabilities, dams are also significant barriers to fish and wildlife, preventing the movement of fish and other aquatic life to feed, spawn, or migrate past the dams.

Assessment Methods

Structure Selection

Files maintained by the Massachusetts Office of Dam Safety (ODS) were reviewed to develop an initial inventory and gather available information on the dams in both Towns. Forty-seven (47) dams were identified during this initial review (see **Figure 4-6** and **Figure 4-7**). Dams were then prioritized for assessment based on ownership and current use. Flood control dams (e.g., Buffumville Dam) were excluded from the assessment. Twenty (20) dams were selected for further assessment.

Limited Visual Condition Assessments

Limited visual condition assessments were conducted in November and December 2018. Assessments were conducted following standardized dam safety inspection protocols using a form adapted from the Massachusetts Office of Dam Safety Phase 1 Formal Dam Safety Inspection Checklist. The inspection form includes the following information:

- Classification information (current size, hazard classification, condition, name, location, purpose, etc.)
- Deficiencies and condition of each part of the structure (embankment, dikes, upstream face, downstream face, appurtenances, walls, concrete structures, masonry structures, spillways, etc.)

Completed inspection forms and relevant file review information for each dam assessed is provided in a separate *Dams Assessment Technical Memorandum* (Fuss & O'Neill, 2019b) (**Appendix C**).

Of the 20 dams selected for limited visual condition assessment, visual inspections were conducted of 14 dams. Access to 6 dams was either unavailable or denied by the land owner. Nine (9) unregistered dams were discovered and observed from the public right-of-way during the field assessments. All 6 dams that were not inspected had sufficient information in the ODS files such that the file review information was used to assess and make recommendations for those dams. Sufficient information was gathered in the field to make additional recommendations for 3 of the unregistered dams in Charlton. **Figure 4-6** and **Figure 4-7** show the locations of the assessed dams.

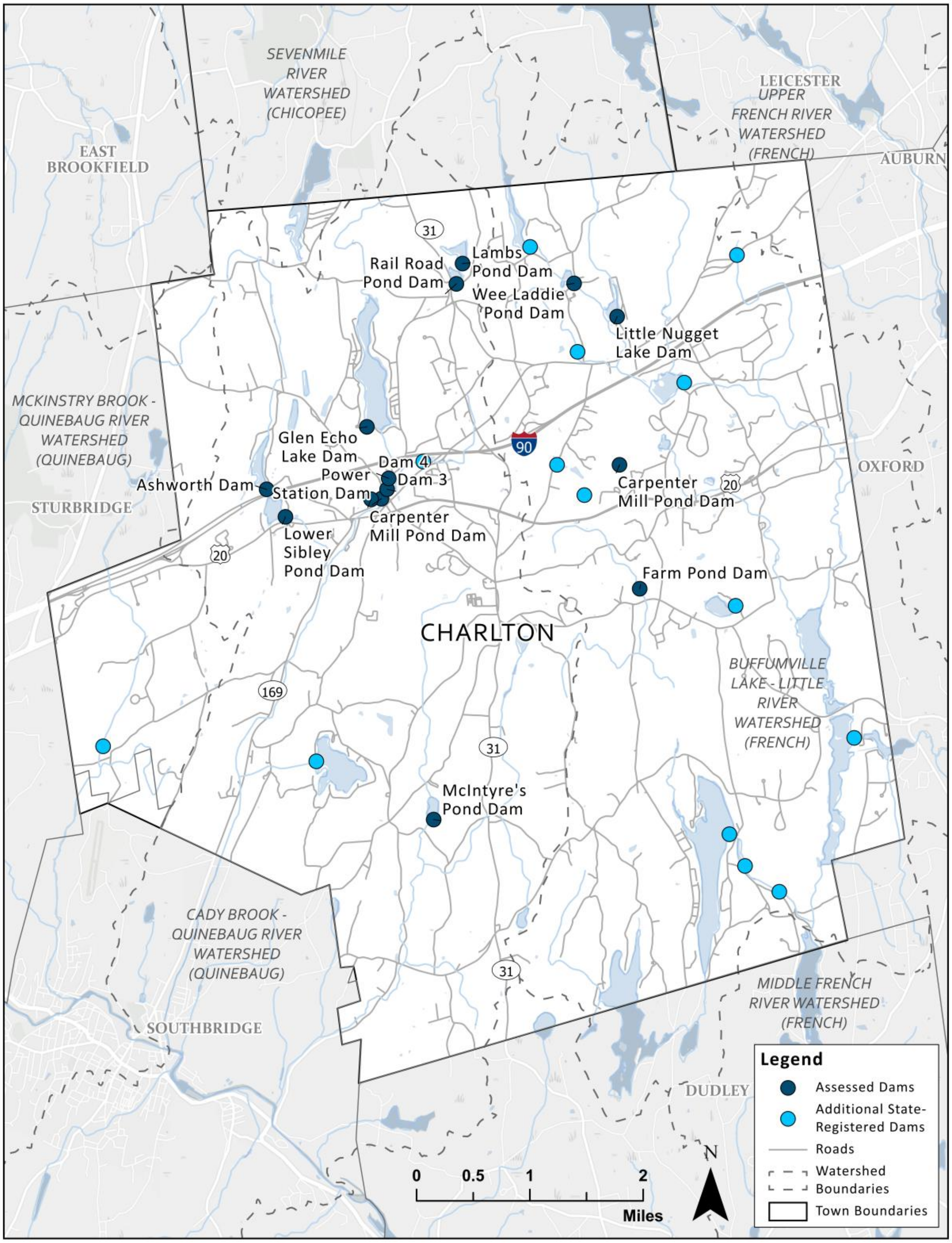


Figure 4-6. Registered dams (all points) and assessed dams (dark blue points) in Charlton.

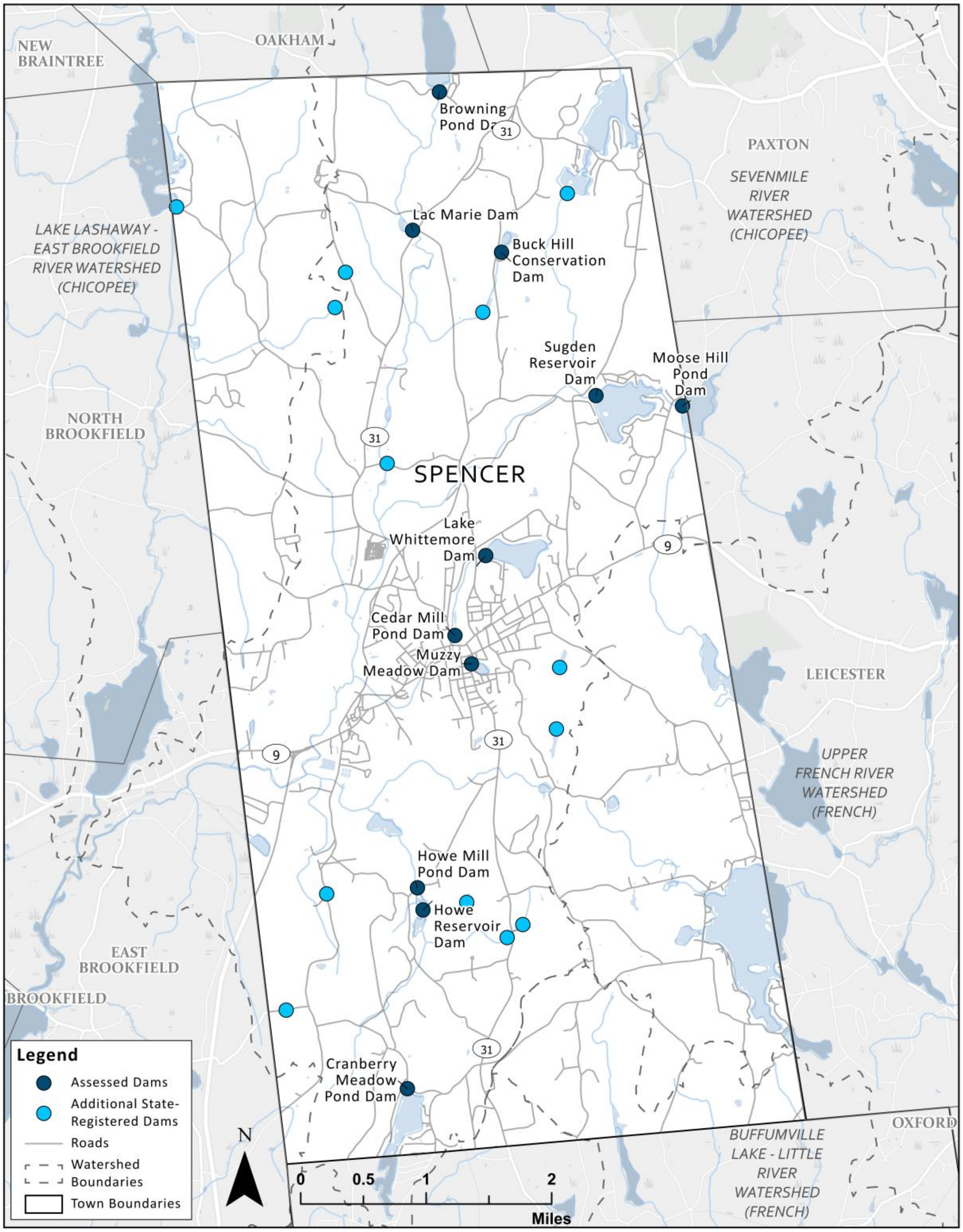


Figure 4-7. Registered dams (all points) and assessed dams (dark blue points) in Spencer.

Evaluation of Management Alternatives

Using data from the limited visual condition assessments and available ODS file data, various management alternatives were evaluated for each dam to identify and prioritize management actions that would enhance flood resiliency and provide ecological benefits. The following dam management alternatives were assessed using the evaluation criteria in the flowchart in **Figure 4-8**.

- **Removal/Breach:** Full removal or partial breach of a dam, thereby eliminating or lowering the impoundment, reducing the risk of failure or breach, and restoring free-flowing conditions. Dam removal eliminates flood risk due to failure or breach, potentially reduces flood risk in upstream areas, meets aquatic organism passage objectives, and eliminates significant liability and costly maintenance for dam owners.

- **Repair:** Repair of structural components of a dam to address existing deficiencies that threaten the structural integrity of the dam, thereby reducing the potential for failure or breach during large storms. The dam repair alternative alone does not eliminate the risk of failure nor does it improve aquatic organism passage. In some cases, the repair option, potentially combined with provision of aquatic organism passage, may be the only viable alternative if removal is not feasible. Dam repair involves the up-front cost of the repairs and a long-term financial commitment to inspect and maintain the dam following the initial repairs. It also assumes that the owner has the willingness, ability, and financial resources to adequately maintain the dam.

- **Modification/Repurposing:** Modification of an existing dam to provide increased storage during floods. For example, repurposing could include increasing the elevation of the dam, dredging of the impoundment, or modification of the outlet structure to significantly reduce the impoundment size and normal pool elevation, allowing the river to flow freely under normal conditions (i.e., a dry impoundment), but allowing the impoundment to fill up and store floodwaters during larger storms. Repurposing of dams for hydropower was not considered because hydropower is generally not economically viable at the scale of the dams located within these towns.

- **Aquatic Organism Passage Structure:** Construction of an engineered structure at a dam to provide for passage of fish and other aquatic organisms, including fishways such as fish ladders, rock ramps, or bypass channels. This option provides enhanced stream continuity if dam removal is not feasible.

- **No Action/Maintain:** Maintain the dam in its current condition.

Factors considered in the alternatives evaluation included current uses and recreational/cultural value of the dam and impoundment, the owner's ability to maintain the dam, failure risk (based on hazard classification and structural condition), flood mitigation potential, and stream continuity and aquatic habitat quality. These factors are described in the flowchart in **Figure 4-8**. A recommended alternative was developed for each dam based on the evaluation criteria and flowchart.

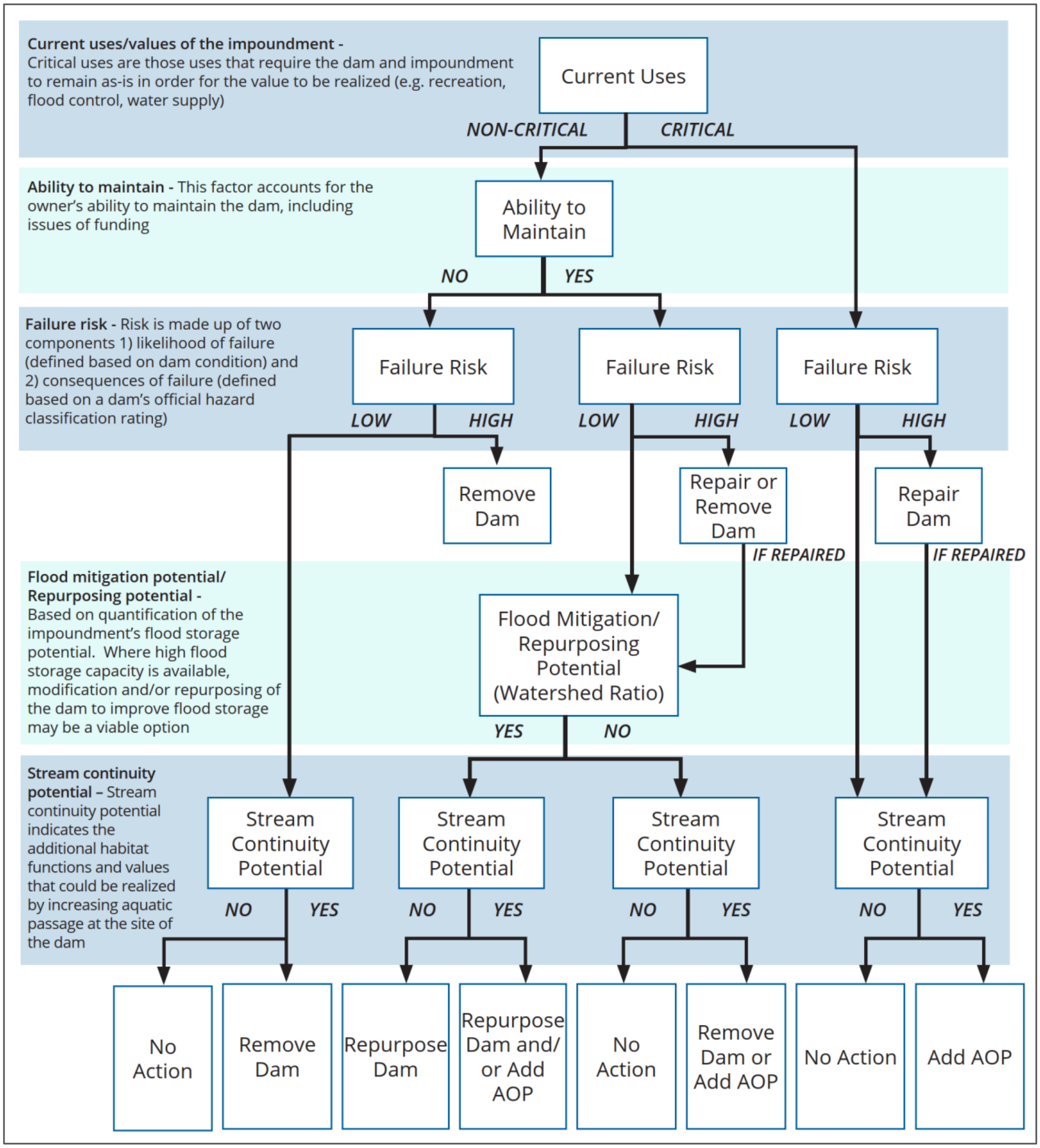


Figure 4-8. Dam management alternatives evaluation criteria flowchart.

Assessment Findings

The following common issues were observed at the assessed dams:

- **Beaver Activity:** Several of the dams (Wee Laddie Pond Dam, Buck Hill Conservation Dam, Lambs Pond Dam, Howe Reservoir Dam, and Little Nugget Lake Dam) were observed to have beaver activity impacting the spillway. In addition, a beaver dam was reported at the spillway of McIntyre's Pond Dam in 2006, though it is unclear if the beaver dam still exists. Beaver dams built at dam spillways have raised the impoundment level by one (1) foot or more at Wee Laddie Pond Dam and Lambs Pond Dam, raising the risk that the dam(s) will overtop during wet periods. The Conservation Agent for the Town of Charlton has also reported that beaver activity is a problem at the majority of the dams managed by the Town.

- **Trees and Vegetation on the Embankment:** The majority of the assessed dams have vegetation encroaching on or growing directly on the dam embankment. Vegetation, especially large trees, can promote the formation of voids in the dam embankment, leading to seepage and piping through the dam, thereby accelerating the degradation of the dam. Trees and vegetation should be cleared back to a distance of 20 feet from any dam and a cover of healthy grass should be maintained on the dam embankment.

- **Lack of Maintenance:** Previous inspection reports stated that Operation and Maintenance (O&M) Plans were not in place for the majority of the dams as of the last inspection. Maintenance is critical at dams to prevent small problems from accumulating and leading to failure of the dam. Dam owners should be encouraged to develop and follow O&M plans to maintain the stability and safety of the dam(s) under their care.

Detailed findings of the assessment are provided in the *Dams Assessment Technical Memorandum* (Fuss & O'Neill, 2019b) (**Appendix C**). **Section 5** summarizes recommended adaptation measures for the medium and high priority dams that were assessed.

4.3 Water and Wastewater Infrastructure

Why is Water and Wastewater Infrastructure Vulnerable?

Water and wastewater infrastructure, such as public drinking water source wells, water distribution systems, wastewater collection systems, and wastewater treatment facilities, are vital for providing clean drinking water and properly disposing of wastewater. These facilities, however, can be vulnerable to flooding as a result of as extreme precipitation events, which are expected to become more frequent and intense given current climate change projections. Flooding may lead to damage to facilities and critical equipment and loss of power, among other issues. Implementing adaptation measures, such as barriers, drainage swales, and elevating equipment, can help protect water and wastewater facilities from the effects of flooding.

Assessment Methods

Identification of Vulnerable Facilities

Spatial mapping and attribute data were compiled for both towns, including FEMA Flood Insurance Rate Maps (FIRMs). Using this data, vulnerable facilities were identified as those that are:

- Located within or adjacent to the area inundated by the 1 percent annual chance (100-year) flood, the 0.2 percent annual chance (500-year) flood, or regulatory floodway, or
- Facilities within or in close proximity and hydraulically connected to a mapped flood hazard area, with critical infrastructure located at or below the published base flood elevation, where available.

The elevation of adaptation measure (i.e., critical elevation) was determined from the 1 percent annual chance flood elevation reported on FEMA FIRMs plus three feet of freeboard, which is consistent with recommended guidance for critical facilities and also accounts for potential increases in peak streamflow under projected future climate change conditions. Where base flood elevations were not determined by FEMA (e.g., Zone A), the 1 percent annual chance flood elevation was estimated from LIDAR ground elevations and the 1 percent annual chance flood hazard boundary in the vicinity of the site depicted on the FEMA FIRMs.

Using these criteria, eight vulnerable facilities in Charlton and five vulnerable facilities in Spencer were identified. **Table 4-1** lists the vulnerable facilities and corresponding 1 percent annual chance flood elevations and critical elevations.

Table 4-1. Ground elevations, 1 percent annual chance flood elevations, and critical elevations at vulnerable facilities.

Facility	LIDAR Ground Elevation (ft.)	1% Annual Chance Flood Elevation (ft.)	Critical Elevation (1% Annual Chance Flood Elevation + 3 Feet of Freeboard)
Town of Charlton			
Old Worcester Pump Station	786.6	780.0*	783.0
North Main Street Pump Station	860.2	855.0*	858.0
Muggett Hill Road Pump Station	683.8	683.0*	686.0
South Sturbridge Road Pump Station	645.2	645.0	648.0
Stevens Park Road	772.8	777.0*	780.0
Route 20 (MTA 5E) Pump Station	637.0	638.0*	641.0
J Hammond Road (MTA 6W) Pump Station	885.5	885.0*	888.0
Pressure Regulating Vault	820.0	817.0*	820.0
Town of Spencer			
Sevenmile River Wellfield	631.3	635.5	638.5
Cranberry Wellfield	634.6	642.0	645.0
Meadow Road Pump Station	635.0	634.5	637.5
UV Disinfection System at WWTF	634.1	641.1	644.1
Low Lying Areas – Adams Street	812.6	816.0*	819.0

*Estimated Flood Elevation - Base flood elevations not determined by FEMA for these locations (e.g., Zone A). Base flood elevations were estimated from LIDAR ground elevations and the 1 percent annual chance flood hazard area boundary depicted on the FEMA FIRM.

Visual assessments were performed at the vulnerable facilities. The assessments included collection of information on relative ground elevations (by LIDAR), equipment locations, power supply and reliability, chemical storage, obvious inflow sources, erosion potential, structural components and general condition, and HVAC controls.

Assessment Findings

The general findings of the assessments are summarized in **Table 4-2**. The full results of the assessment are documented in a separate *Water and Wastewater Vulnerability Assessment Technical Memorandum* (Fuss & O'Neill, 2019c) (**Appendix D).** Recommended adaptation measures are outlined in **Section 5**.

Table 4-2. Assessment findings for vulnerable water and wastewater facilities in Charlton and Spencer.

Facility	Assessment Findings
Town of Charlton	
Old Worcester Pump Station	- Located in proximity to 500-year flood zone - Station and critical equipment (backup generator, automatic transfer switch, power transformer, control panel, two pumps, and a sump) are located below grade
North Main Street Pump Station	- Adjacent to 500-year flood zone - Station and critical equipment (backup generator, automatic transfer switch, power transformer, control panel, two pumps, and the sump) below grade
Mugget Hill Road Pump Station	- Located in proximity to 100 and 500-year flood zones - Station and critical equipment vulnerable to flooding
South Sturbridge Road Pump Station	- Located within 100 and 500-year flood zones - Critical equipment, electrical cabinet, and the ventilation system are below the 100-year flood elevation
Stevens Park Road Pump Station	- Located in an area prone to surface runoff flooding - Previous runoff has caused stress on the fence posts and the conduit (concrete pad has been lifted)
Route 20 (MTA 5E) Pump Station	- Located in a 100-year flood zone - Lower levels have components vulnerable to flooding (conduits and receptacles are protected and watertight)
J Hammond Road (MTA 6W) Pump Station	- Located in a 500-year flood zone - Lower levels have components vulnerable to flooding (conduits and receptacles are protected and watertight)
Pressure Regulating Vault	- In an area prone to surface runoff and high groundwater levels - Structure faces an increased flooding risk
Town of Spencer	
Sevenmile River Wellfield	- Located within 100-year flood zone and regulatory floodway of Sevenmile River - Well casing is approximately 2.5 feet above the 100-year flood elevation - Power junction box/ conduit vulnerable to damage during significant rain/flooding events
Cranberry Wellfield	- Located within a 100-year flood zone - Well house is located seven feet above the 100-year flood elevation, with the MCC and electrical control cabinet vulnerable to flooding - Main power transformer is located at ground level, leaving it vulnerable to flooding - The junction box in the storage facility is the only equipment close to ground level, leaving it vulnerable to flooding
Wastewater Pump Station on Meadow Road	- Adjacent to a 100-year flood zone and regulatory floodway of Sevenmile River - The station is less than one foot (+/-) from the 100-year flood elevation, leaving it and its critical equipment (backup generator, liquid propane storage tank, pump control panel, centrifugal pumps, ATS, SCADA control panel) vulnerable to flooding
UV Disinfection System at the Discharge of the Wastewater Treatment Facility	- Top of channel for UV system is 7 feet above 100-year flood elevation for the area, but high waters have been observed in the channel after flooding or during heavy rain, indicating it is potentially vulnerable to flooding
Low Lying Area off Adams Street near Spencer (Muzzy Meadow) Pond	- The sewer collection system in this area and water main on Adams Street are vulnerable to flooding during major rainfall events that cause scour or erosion - The downstream culvert, if blocked, could cause water levels to increase, leading to flooding in the area - The area is known to have a significant infiltration/inflow problem

4.4 Stormwater Infrastructure

Why is Stormwater Infrastructure Vulnerable?

Stormwater runoff from buildings, pavement, and other compacted or impervious surfaces contributes to drainage-related and riverine flooding. Stormwater runoff is also a source of nonpoint source pollution and a cause of water quality impairments, particularly in developed areas of the Towns where impervious cover exceeds 20%. There are a number of drainage-related flooding problems in developed areas of the Towns due to outdated or inadequate drainage systems, and stormwater runoff volumes exacerbate riverine flooding during both small and large storms.

Rainfall in New England is expected to continue to increase due to climate change, which is expected to increase the risk of river-related flooding in the Towns of Charlton and Spencer. Development pressure in the region will continue to result in the conversion of natural areas to impervious surfaces, putting additional stress on existing drainage systems and contributing further to riverine flooding and water quality issues if such development and associated stormwater impacts are not managed appropriately.

Green Infrastructure

Green infrastructure, also referred to as "green stormwater infrastructure" and "low impact development or LID," is an alternative approach to traditional stormwater management. The green infrastructure approach encourages the infiltration of stormwater into the ground close to where precipitation falls, similar to what occurs in undeveloped areas. By using natural materials including vegetation and soils, these practices restore natural stormwater recharge and filtration processes while reducing downstream flooding. Additionally, green infrastructure can be constructed in stages, as funding and resources are available. Unlike traditional drainage systems that need to be constructed in whole to provide any benefit, green infrastructure solutions can provide incremental benefits as they are implemented.

A green infrastructure approach reduces stormwater volumes and runoff rates, reduces the risk of downstream flooding, and provides incremental flood benefits as each component is installed.

Green infrastructure includes a variety of stormwater management practices, such as bioretention, engineered wetland systems, permeable pavement, green roofs, green streets, infiltration planters, tree boxes, and rainwater harvesting. These practices capture, manage, and/or reuse rainfall close to where it falls, thereby reducing stormwater runoff and keeping it out of drainage systems and receiving waters.

In addition to reducing polluted runoff and improving water quality, green infrastructure can improve flow conditions in streams and rivers by infiltrating water into the ground, thereby reducing peak flows during wet weather and sustaining or increasing stream base flow during dry periods, which can be important for aquatic habitat, fisheries, and groundwater supplies. When applied throughout a watershed, green infrastructure can help mitigate flood risk and increase flood resiliency. At a smaller scale, green infrastructure can also reduce erosive velocities and streambank erosion. Green infrastructure and LID are the preferred approach for stormwater management in Massachusetts.

Green Infrastructure Assessment

A green infrastructure assessment was performed for the Towns of Charlton and Spencer to identify green infrastructure retrofit opportunities that increase flood resiliency and improve or protect water quality.

The assessment consisted of: 1) a screening-level evaluation to identify areas with the greatest feasibility for and potential benefits from green infrastructure retrofits, 2) field inventories of the most promising green infrastructure retrofit opportunities in the watershed (see **Figure 4-9**, **Figure 4-10**, and **Table 4-3**), and 3) development of concept designs for 10 retrofit sites. The assessment is documented in a separate *Green Infrastructure Assessment Technical Memorandum* (Fuss & O'Neill, 2019d) (**Appendix E**). **Section 5** presents recommended green infrastructure design concepts and other related recommendations for both communities.

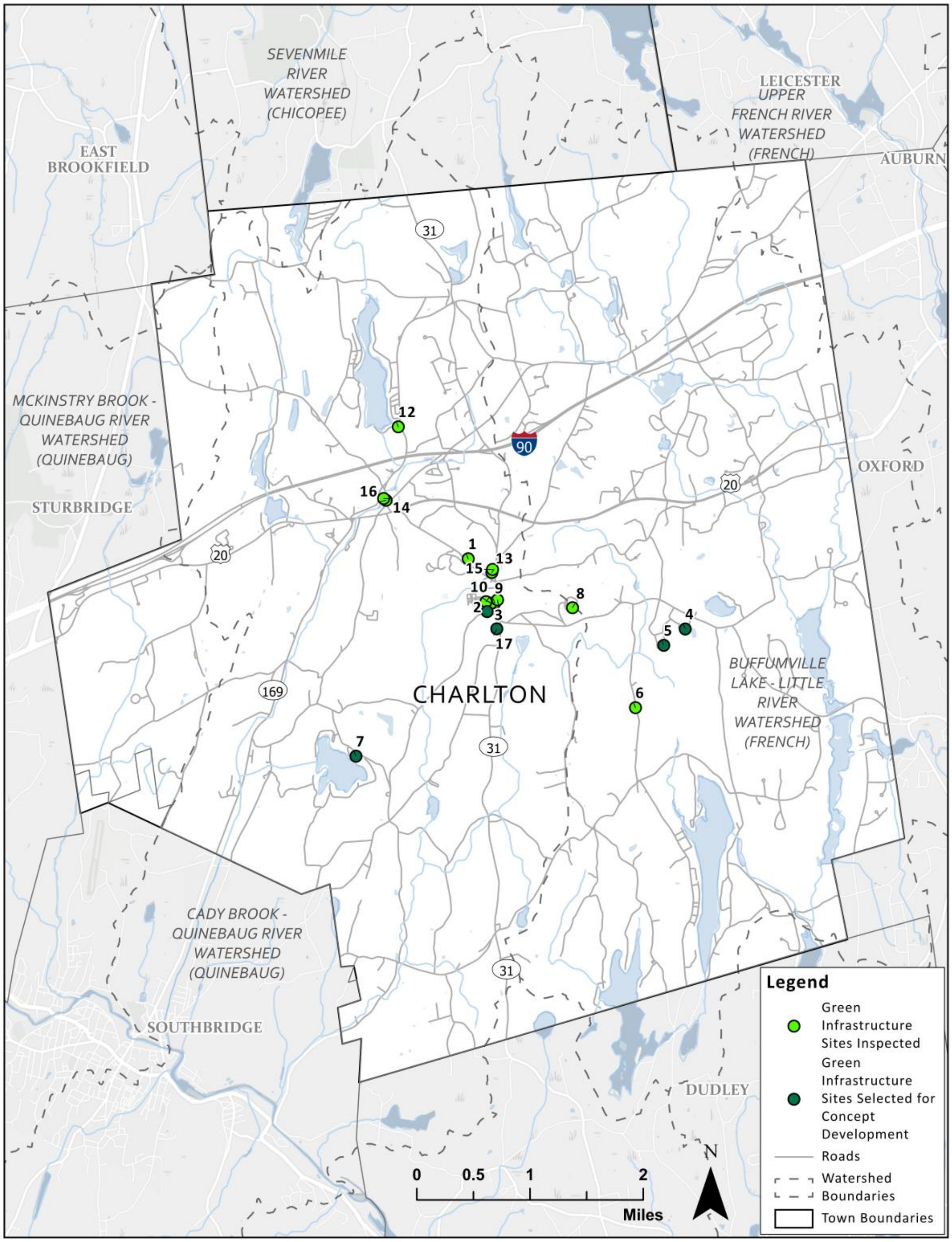


Figure 4-9. Map of potential green infrastructure sites selected for assessment in Charlton. Refer to Table 4-3 for information on each site.

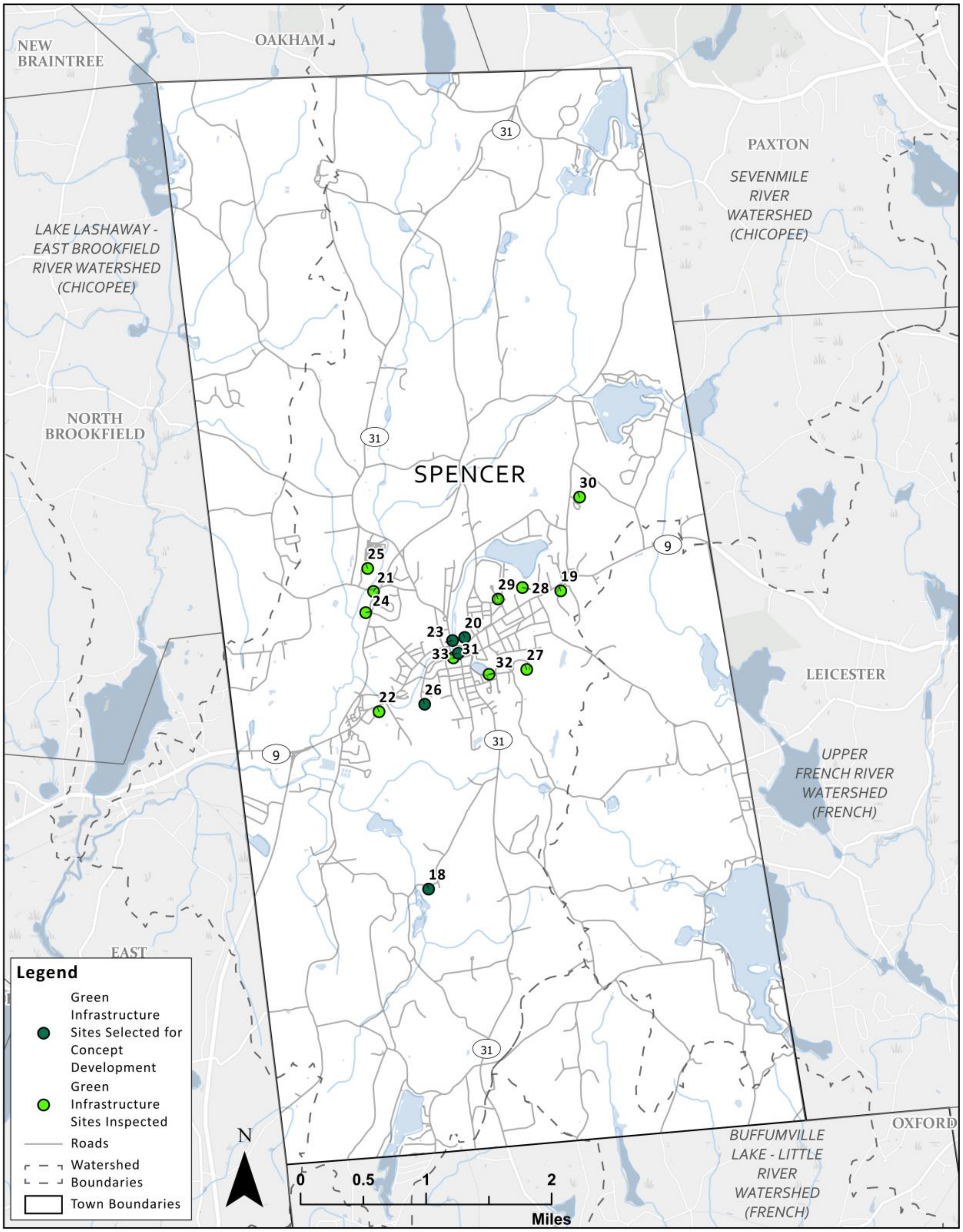


Figure 4-10. Map of potential green infrastructure sites selected for assessment in Spencer. Refer to Table 4-3 for information on each site.

Table 4-3. Potential green infrastructure retrofit sites selected for field investigation.

Site No.	Site Name/Description	Address	Owner
		Town of Charlton	
1	Charlton Police Department	85 Masonic Home Road	Town of Charlton
2	Charlton Municipal Offices (Charlton Town Hall)	37 Main Street	Town of Charlton
3	Open Space in Front of Charlton Town Hall	Route 31 Right-of-Way	Town of Charlton
4	Heritage School	34 Oxford Road	Dudley-Charlton Regional School District
5	Charlton Middle School	2 Oxford Road	Dudley-Charlton Regional School District
6	Charlton Little League	50 Bond Rd and 106 Bond Rd	Charlton Little League, Charlton Youth Soccer Inc.
7	Prindle Lake Park	0 Prindle Hill Road	Town of Charlton
8	Bay Path Vocational School	15 Old Muggett Hill Road	Southern Worcester County
9	Charlton Public Library	40 Main Street	Town of Charlton
10	Fields Behind Charlton Public Library	0 Main Street	Town of Charlton
11	Charlton Elementary School	9 Burlingame Road	Dudley-Charlton Regional School District
12	Glen Echo Lake Access	0 City Depot Road	Commonwealth of Massachusetts
13	United States Post Office	56 North Main Street	David Peters
14	United States Post Office	9 Power Station Road	R&D Alliance LLC (leased to USPS)
15	Charlton Garage	54 North Main Street	Town of Charlton
16	Charlton Fire Department Headquarters	10 Power Station Road	Town of Charlton
17*	Maynard Farms Recreation Area	12 Dresser Hill Road and 0 Burlingame Road	Town of Charlton
		Town of Spencer	
18	Howe State Park	51 Howe Road	Commonwealth of Massachusetts
19	David Prouty High School and Spencer-East Brookfield Regional HS Athletic Fields	302 Main Street	Town of Spencer
20	Spencer Town Hall	157 Main Street	Town of Spencer
21	Powder Mill Park	Meadow Road	Town of Spencer
22	Spencer Police Department Spencer Fire Department Headquarters Spencer Rescue & Emergency Squad	9 West Main Street 11 West Main Street 6 Bixby Road	Town of Spencer Town of Spencer Spencer Rescue & Emergency Squad
23	Richard Sugden Library	117 Main Street	Town of Spencer
24	Spencer Water & Sewer Department	3 Meadow Hill Road	Town of Spencer
25	Spencer Fairgrounds	46 Smithville Road	Town of Spencer
26	O'Gara Park	Valley Street	Town of Spencer
27	Knox Trail Junior High School	73 Ash Street	Town of Spencer
28	Luther Hill Park Laurel Hill Park	19 Park Street 269 Main Street	David P. Durgan Town of Spencer
29	Lake Street School (public amenity portion)	17 Lake St and 42 Highland Ave	Town of Spencer
30	Wire Village School	60 Paxton Road	Town of Spencer
31	Intersection of Lloyd Dyer and Wall Streets	Wall St and Lloyd Dyer St	Town of Spencer
32	Clark Street Outfall to Muzzy Meadow Pond	Clark Street	Town of Spencer
33	Mechanic Street Parking Lot	14, 18, and 20 Mechanic Street	Town of Spencer

5 Adaptation Recommendations

This section describes recommended adaptation measures that the Town of Charlton and the Town of Spencer can take to reduce the vulnerability of their water infrastructure to flooding and climate change impacts. The adaptation measures include **site-specific measures** focused on water-related infrastructure at a single location (e.g., a specific road-stream crossing, dam, green infrastructure retrofit site, or water/wastewater facility) as well as **policy or regulatory measures** to increase resilience town-wide.

Adaptation means anticipating the adverse effects of climate change and taking appropriate action to prevent or minimize the damage they can cause, or taking advantage of opportunities that may arise. Well-planned, early adaptation action can save money and lives later.

Implementation of the adaptation recommendations identified in this plan will require significant financial and technical assistance. The adaptation recommendations are not intended to be implemented all at once, but are meant to be implemented over time by the Towns and other public and private partners, with grants and additional sources of funding. The plan recommendations include short-term and long-term measures, which could be implemented as funding becomes available and when opportunities arise. For example, a stream crossing replacement or green infrastructure installation may be more cost-effective if implemented in conjunction with a planned roadway improvement project.

The Towns should implement high-priority site-specific adaptation measures in combination with policy/regulatory measures. Well-informed municipal policies and regulations can help communities become more resilient to flooding by preserving undeveloped land in the watershed, siting development in locations less vulnerable to flooding, and promoting designs that reduce runoff and are less likely to be damaged in a flood. In terms of site-specific adaptation measures, the communities should focus on implementing priority water and wastewater infrastructure upgrades, dam repairs, replacing and upsizing high-priority road stream crossings, and implementing green infrastructure retrofits. These types of projects will have more immediate and tangible flood resilience benefits by upgrading vulnerable infrastructure and providing highly visible projects with other public benefits.

The remainder of this section describes the recommended adaptation measures presented in this resiliency plan, organized by water infrastructure type. Each sub-section includes an adaptation goal statement, a brief description of the flood-related vulnerabilities, and a description of recommended adaptation measures including a proposed timeframe and key partners for implementing the recommendations. Planning-level cost estimates are provided for some site-specific recommendations, while relative costs or a range of typical costs are presented for other recommendations. Recommendation summaries tailored to each town are provided in **Appendices F and G**.

5.1 Road-Stream Crossings

Adaptation Goal: Reduce the flood and erosion hazards posed by culverts and bridges, and restore stream connectivity for fish and other aquatic organisms.

Replacing Outdated or Inadequate Crossings – Stream and Flood Friendly Culverts

Replacing outdated or inadequate crossings with crossings that maintain natural flow and substrate conditions enhances the resiliency of the transportation system, reduces expensive erosion and structural damage, reduces flood impacts on upstream and neighboring properties, and increases stream continuity for aquatic organism passage. Better standards and more effective design are critical for enhancing the resiliency and ecological benefits of new and replacement stream crossings. The text box on the following page highlights common stream crossing standards and elements of effective crossing designs.

Massachusetts has adopted stream crossing standards that promote stream continuity and flood resilience. The *Massachusetts River and Stream Crossing Standards* (*Stream Crossing Standards*) serve as comprehensive, state-specific guidance for the Commonwealth and were last revised in 2012. The *Massachusetts Stream Crossings Handbook*, prepared by the Division of Ecological Restoration, incorporates the *Stream Crossing Standards*, while the U.S. Army Corps of Engineers' Massachusetts General Permit and the Massachusetts 401 Water Quality Certification require these or similar standards be met. Further, the Massachusetts Wetlands Protection Act requires all new crossings to meet the *Stream Crossing Standards* and all replacement crossings to meet the standards to the maximum extent practicable. The Massachusetts Department of Transportation's *Stream Crossing Handbook* was originally published in 2010 as guidance for the design of bridges and culverts for wildlife passage at freshwater streams. MassDOT is in the process of updating its *Handbook* to reflect current best crossing practices, current stream crossing regulations, and technical guidance for municipalities.

> Well-designed crossings should span the stream and banks, maintain comparable water velocities, have a natural streambed, and create no noticeable change in the river.

Crossings designed to meet the *Massachusetts River and Stream Crossing Standards* have been found to be extremely effective in safely passing water, sediment, and debris during floods, while remaining viable routes for emergency personnel and residents (MADER, June 2012). While upgrading culverts to larger and more flood-resilient and stream-friendly designs can be up to 50%-100% more expensive than in-kind replacements in the short term, long-term costs are significantly reduced as the road crossing is able to survive larger precipitation events and generally requires less maintenance. When maintenance and replacement are considered, the average annual cost of an upgraded crossing can be lower over its lifetime than that of an undersized crossing over the same time (Industrial Economics, Incorporated, January 2015; Levine, August 2013; Gillespie, et al., February 2014). Upgraded stream crossings are even more cost-effective when climate change considerations (e.g., more frequent intense storms) are factored in.

Massachusetts River and Stream Crossing Standards

Crossing Type

Bridges and bottomless arches, 3-sided box culverts, and open-bottom culverts are preferred and should be used whenever possible.

Embedment

Box and pipe culverts, if used, should be embedded into the streambed to at least 20 percent of the culvert height at the downstream invert (a minimum of 2 feet), used only on "flat" streambeds (slopes no steeper than 3 percent), and installed level.

Substrate

Natural substrate (rocks, gravel, etc.) should be used within the crossing, and it should match the upstream and downstream substrates. It should resist displacement during floods and should be designed so that appropriate material is maintained during normal flows.

Crossing Span/Width

The crossing opening should be at least 1.2 times the bankfull width of the stream, measured bank to bank at the ordinary high-water level or edges of terrestrial, rooted vegetation.

Openness

The crossing should have an openness ratio (cross-sectional area divided by crossing length) of at least 0.82 feet, with 1 to 1.5 feet preferred. The crossing should be wide and high relative to its length.

Water Depth and Velocity

At low flows, water depths and velocities should be the same as they are in natural areas upstream and downstream of the crossing.

Source: Massachusetts Stream Crossings Handbook (MADER, June 2012)

Recommended Adaptation Measures

Table 5-1 provides a summary of recommended site-specific and policy/regulatory adaptation measures relative to road-stream crossings in the two communities. Site-specific design recommendations and additional discussion of the policy and regulatory recommendations follow the table.

Table 5-1. Adaptation recommendations for road-stream crossings.

Adaptation Measure	Lead Entity	Timeframe	Estimated Cost	Possible Funding Sources
Site-Specific Recommendations				
1. Upgrade existing vulnerable stream crossings by replacing crossings with more resilient and ecologically-friendly designs.	Charlton and Spencer (MassDOT for crossings under state jurisdiction)	5-10+ years and as opportunities arise	$$$ to $$$$$	MVP Action Grants, DER Culvert Replacement Grants, FEMA flood hazard mitigation assistance funding, cost-share grants, third-party compensatory mitigation
Policy and Regulatory Recommendations				
1. Incorporate priority stream crossings identified in this study into local hazard mitigation plans. Update and integrate local comprehensive land use plans and hazard mitigation plans.	Charlton and Spencer, Central MA Regional Planning Commission	1-2 years	$	Municipal funds
2. Update design storm precipitation amounts in local land use regulations and policies to promote more resilient road crossing design.	Charlton and Spencer	2-5 years	$$	Municipal funds
3. Establish adequate, sustained sources of funding.	Charlton and Spencer, State Agencies	Ongoing	$$	See Site-Specific Recommendation 1
4. Provide training to highway departments.	Charlton and Spencer, MassDOT	2-5 years	$$	Municipal/state funds
5. Implement ongoing inspection and maintenance programs.	Charlton and Spencer	1-2 years and ongoing	$$	Municipal funds

$ = $0 to $5,000 $$ = $5,000 to $10,000 $$$ = $10,000 to $50,000 $$$$ = $50,000 to $100,000
$$$$$ = Greater than $100,000

Site-Specific Recommendations

1. ***Upgrade existing vulnerable stream crossings by replacing crossings with more resilient and ecologically-friendly designs.***

The Town of Charlton and the Town of Spencer should replace existing vulnerable stream crossings with more flood-resilient and ecologically-beneficial designs. Replacement stream crossings should be upgraded to meet the *Massachusetts River and Stream Crossing Standards* whenever feasible.

The road-stream crossing vulnerability assessments classified stream crossings in the Towns of Charlton and Spencer as high, medium, or low priority for upgrade or replacement. **Table 5-2** lists the top-ranked high priority stream crossings by town and subwatershed. A complete list of all of the assessed stream crossings, including additional high, medium, and low priority crossings, is provided in the technical memorandum in **Appendix B**.

Note that the priority ratings are relative. Upgrade or replacement of higher-rated or higher-priority structures will generally provide greater overall benefits relative to flood resiliency and stream continuity based on a number of factors. The priority ratings are not meant as definitive recommendations since the ratings do not account for cost and other site-specific factors. The individual assessment ratings (i.e., hydraulic capacity, flooding impact potential, geomorphic vulnerability, and aquatic organism passage) should also be considered on a case-by-case basis when evaluating replacement and upgrade of specific structures. Crossings that are rated as medium or low priority overall, based on consideration of all four factors, may still be good candidates for replacement or upgrade to achieve a particular objective such as increased hydraulic/geomorphic capacity or aquatic organism passage.

The text box following **Table 5-2** provides a recommended approach for implementing crossing replacements based upon the vulnerability assessment priority ratings, as well as additional required site-specific data collection and analysis for permitting and design of individual crossings.

Crossing replacement design concepts were developed for the 10 highest rated stream crossings that were assessed. The concepts are intended to enhance the resilience of the stream crossings and river system by better accommodating extreme flows, providing for the passage of debris during floods, and providing for passage of aquatic organisms under normal flow conditions. At several of the crossings, recommendations are also provided for channel or floodplain restoration in upstream or downstream areas along with the proposed crossing upgrades to enhance flood resilience, water quality, and aquatic habitat using a combination of natural and infrastructure-based approaches. Each two-page concept includes a description and photographs of existing conditions, key data and findings from the field assessment, a description of the proposed design concept, and a plan view drawing of the site conditions and proposed replacement crossing.

Planning-level cost estimates are also provided for each of the replacement concepts. Estimated costs are presented as screening-level cost ranges. The estimated costs include anticipated design and construction costs, which are based on costs of recent similar stream crossing replacement projects in the northeastern U.S.

Table 5-2. Top-ranked high priority crossings: road-stream crossing vulnerability assessment and prioritization results summary.

Road Name	Town	HUC 12 Watershed Name	Impact Score	Existing Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Value	Scaled Crossing Priority	Relative Priority Rating
Wire Village Rd	Spencer	Sevenmile River	3	15	15	12	15	25	15	45	0.9	High
Elm St	Spencer	Sevenmile River	5	25	25	10	5	15	25	45	0.9	High
Water St	Spencer	Sevenmile River	5	0	0	15	25	12	25	43.5	0.87	High
Mill St	Spencer	Sevenmile River	5	25	25	25	15	9	25	42	0.84	High
May St	Spencer	Sevenmile River	5	25	25	20	10	6	25	40.5	0.81	High
Valley St	Spencer	Sevenmile River	5	15	20	10	25	3	25	39	0.78	High
Gold Nugget Rd	Spencer	Sevenmile River	4	20	20	16	8	12	20	36	0.72	High
East Baylies Rd	Charlton	Cady Brook-Quinebaug R.	4	20	20	12	20	9	20	34.5	0.69	High
Stafford St	Charlton	Cady Brook-Quinebaug R.	4	20	20	16	8	9	20	34.5	0.69	High
Blood Rd	Charlton	Cady Brook-Quinebaug R.	4	20	20	12	8	9	20	34.5	0.69	High
Center Depot Rd	Charlton	Cady Brook-Quinebaug R.	4	20	20	12	8	9	20	34.5	0.69	High
Freeman Rd	Charlton	Cady Brook-Quinebaug R.	4	16	20	12	4	9	20	34.5	0.69	High
Brooks Pond Rd	Spencer	Lake Lashaway-E. Brookfield	4	20	20	12	20	9	20	34.5	0.69	High
Wire Village Rd	Spencer	Sevenmile River	4	4	8	16	20	9	20	34.5	0.69	High
Greenville St	Spencer	Upper French R.	4	20	20	12	8	9	20	34.5	0.69	High
Marble Rd	Spencer	Upper French R.	4	20	20	16	4	9	20	34.5	0.69	High

Recommended Approach for Stream Crossing Replacement

- Start with high-priority crossings identified in this assessment.
- Consider other upstream and downstream crossings (including additional high-priority, intermediate- and low-priority crossings) on the same river/stream system.
- Generally replace downstream crossings first to:
  1. Avoid inadvertently increasing downstream peak flows at outdated or undersized stream crossings by enlarging upstream crossings, and
  2. Open up stream segments to passage of fish and other aquatic organisms by starting downstream and progressing upstream.

  The more upstream community (typically Spencer) should coordinate with the downstream community (Charlton) and other neighboring communities to implement projects on shared river systems.
- Lower-priority crossings downstream of high priority crossings should be considered for replacement if they are hydraulically undersized, have high geomorphic vulnerability, or are in poor structural condition.
- Include priority crossings in municipal Capital Improvement Plans.
- Implement upgrades as part of planned capital improvements such as road rehabilitation or reconstruction.
- Perform site-specific data collection, geotechnical evaluation, hydrologic and hydraulic evaluation, and structure type evaluation to support design and permitting (see below for typical requirements).

Site Assessment Needs for Stream Crossing Replacement

Geotechnical Evaluation

Perform subsurface investigation and soils analysis.

Site Reconnaissance and Wetland Delineation

Delineate wetlands, perform a riverbed substrate analysis to understand the existing riverbed substrate and provide data to calculate the design bed material; identify the type and integrity of stream grade controls; identify and flag bankfull width measurement locations and representative cross-sections to be surveyed upstream and downstream of culvert; determine appropriate reference reaches.

Topographic Survey

Perform topographic survey and include other relevant features such as wetlands and waterbodies, headwall/wingwall locations and elevations, centerline elevation of the road, and geotechnical boring locations, river longitudinal profiles, culvert invert elevations, top of culvert, representative cross-sections above and below the culvert, mean annual high water, property lines and roadway right-of-way.

Hydrologic and Hydraulic Study

Conduct a detailed hydrologic analysis of the site, using appropriate methods. Identify typical low flows, the bankfull discharge, and peak flows required for the engineering and design process. The hydraulic analysis should assess existing water depths, velocities and water surface profiles and potential upstream and downstream impacts of stream crossing modifications.

Traffic Analysis

Analyze the traffic over the project culvert, including volume, peak volume, and type of vehicle traffic.

Structure Type Selection

Compare various crossing types (3-sided culverts, arches, embedded box culverts, and large diameter pipes) based on relative construction cost, ease of construction, and anticipated benefits. For recommended alternative, provide opinion of probable cost and structure characteristics.

Wire Village Road at Unnamed Tributary to Turkey Hill Brook
Culvert Replacement Concept
Spencer, MA

Site Description

Wire Village Road crosses an unnamed tributary to Turkey Hill Brook (crossing code xy42267367198603. The crossing consists of a single, 37-foot long, 2-foot diameter corrugated metal pipe which projects out from the embankment at the outlet and terminates in a 3.7-foot freefall onto a cascade of rocks to reach the stream bottom. The structure severely constricts the stream's 14-foot bankfull width. These combined conditions present significant barriers to aquatic passage at a site which has a high Index of Ecological Integrity rating, an indicator of stream habitat quality and overall ecological benefit of removing an existing barrier. Embankment piping was also noted during the field assessment, which resulted in an elevated structural risk score. The existing structure is undersized for all evaluated return interval peak flows, including the existing 10-year peak flow.

Proposed Concept

- Replace the existing undersized culvert with a 17-foot span bridge to accommodate the 1.2 times bankfull width design standard of the Massachusetts River and Stream Crossing Standards. Reconstruct the stream channel and banks through the crossing to match the existing channel and banks, including stream substrate and slope.
- The proposed culvert replacement design concept will:
  - ➢ Provide increased hydraulic capacity to reduce risks from flooding and road overtopping
  - ➢ Reduce geomorphic risk associated with freefall conditions and the fact that the crossing slope is significantly less than that of the natural channel
  - ➢ Eliminate a significant barrier to aquatic passage in a high-value habitat area

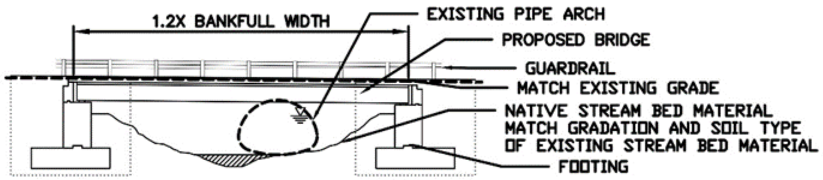


Image 4: Typical detail of a replacement bridge designed to meet the MA River and Stream Crossing Standards

Image 1: View of outlet freefall condition looking downstream from crossing outlet during field assessment on November 6, 2018.

Image 2: View of outlet freefall condition at crossing during field assessment on November 6, 2018.

Image 3: View of crossing inlet during field assessment on November 6, 2018.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.9
Impact Score (1-5): 3
Hydraulic Risk Score (1-25) (Existing/Future): 15/15
Geomorphic Risk Score (1-25): 12
Structural Risk Score (1-25): 15
AOP Benefit Score (1-25): 25

Existing Crossing Characteristics

Material: Corrugated metal pipe
Structure Width: 2 feet
Structure Height: 2 feet
Structure Length: 37 feet
Bankfull Width: 14 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.1 miles^2
Existing Structure Capacity: 13.3 cfs
Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	23 cfs	28 cfs
25-year	33 cfs	39 cfs
50-year	41 cfs	49 cfs
100-year	50 cfs	59 cfs

Notable Assessment Findings

Freefall condition at outlet
Severe constriction
Embankment piping noted
High ecological benefit to crossing removal
Undersized for all evaluated peak flows

Estimated Replacement Cost Range

Total project cost: $400K to $500K

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Wire Village Road, Spencer, MA

Culvert Replacement Concepts, Charlton & Spencer, MA

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Elm Street and Valley Street at Unnamed Tributary to Sevenmile River
Culvert Replacement Concept
Spencer, MA

Site Description

Valley Street and Elm Street cross an unnamed tributary to the Sevenmile River approximately 300 feet from Route 9. The Valley Street crossing is about 200 feet downstream of the Elm Street crossing. The Elm Street crossing consists of two concrete box culverts, each of which is 5 feet wide and 3.3 feet high while the Valley Street crossing consists of a 6.5-foot wide by 5.5-foot tall concrete box/bridge. A nearly 12-foot freefall is present at the outlet of the Elm Street crossing. The Elm Street crossing is hydraulically undersized for all evaluated return interval peak flows. The Valley Street structure is poorly aligned with the stream, creating a sharp bend at the inlet and the stream channel is severely constricted relative to the bankfull width. The Valley Street crossing has high structural risk due to erosion and undermining of concrete footings. A secondary structure enters the Valley Street structure just below the crossing outlet. Both crossings are channelized and armored and are located in the densely developed town center area, resulting in high flood impact potential.

Proposed Concept

- Elm Street: Replace the existing undersized culvert with a bridge of minimum 12-foot span and lower invert for limited aquatic passage
- Valley Street: Replace the existing undersized crossing with a 12-foot span bridge. Determine the origin of the secondary pipe and evaluate green infrastructure to infiltrate or retain runoff from the contributing drainage area, redesigning the crossing to better integrate the two structures
- Reconstruct stream channel and banks through both crossings to match existing channel and banks, stream substrate, and slope
- The proposed culvert replacement design concepts will:
  - ➢ Provide increased hydraulic capacity
  - ➢ Reduce geomorphic risk
  - ➢ Provide limited improvements to aquatic organism passage (Elm Street)
  - ➢ Alleviate failure risks due to undermining of the structure (Valley Street)
  - ➢ Explore potential to decrease peak flows by reducing runoff from secondary drainage structure (Valley Street)

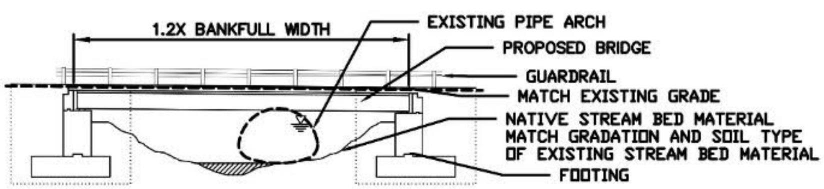

Image 4: Typical detail of a replacement bridge designed to meet the MA River and Stream Crossing Standards.

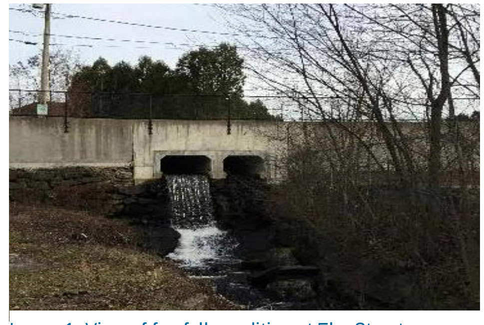

Image 1: View of freefall condition at Elm Street crossing outlet during field assessment on November 12, 2018.

Image 3: View of bank armoring below the Valley Street crossing outlet.

Image 3: View of Valley Street crossing outlet and secondary structure (left) during field assessment on November 12, 2018.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.78 to 0.9
Impact Score (1-5): 5
Existing Hydraulic Risk Score (1-25): 15 to 25
Future Hydraulic Risk Score (1-25): 20 to 25
Geomorphic Risk Score (1-25): 10
Structural Risk Score (1-25): 5 to 25
AOP Benefit Score (1-25): 3 to 15

Existing Crossing Characteristics

Material: concrete
Structure Width: 5 feet to 6.5 feet (per opening)
Structure Height: 3 to 5.5 feet
Structure Length: 23 to 32 feet
Bankfull Width: approximately 10.5 feet

Hydraulic Capacity Summary

Total Drainage Area: 1.7 miles^2
Existing Structure Capacity: 167 cfs to 266 cfs
Estimated Peak Flows:

Recurrence Interval	Existing (cfs)	Future (cfs)
10-year	180 to 181 cfs	216 to 217 cfs
25-year	248 to 249 cfs	298 to 299 cfs
50-year	306 to 308 cfs	367 to 370 cfs
100-year	369 to 371 cfs	443 to 445 cfs

Notable Assessment Findings

12-foot freefall (Elm)
Undersized for all evaluated peak flows (Elm)
Poor alignment with stream (Valley)
Erosion and undermining (Valley)

Estimated Replacement Cost Range

Elm Street: $400K to $500K
Valley Street: $300K to $400K

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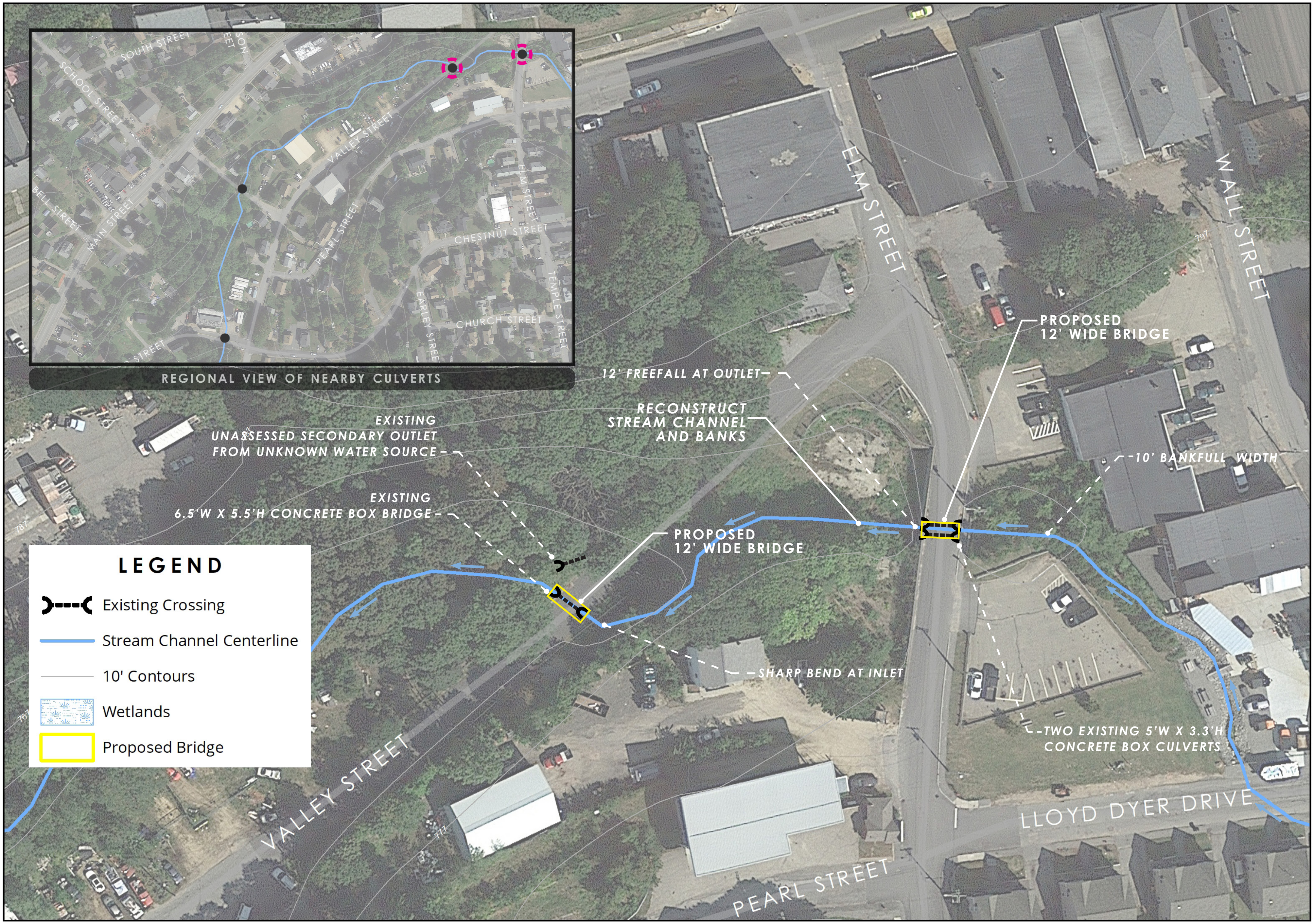

Elm Street & Valley Street, Spencer, MA

Culvert Replacement Concepts, Charlton & Spencer, MA

0 50 100 Feet

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Water Street at Unnamed Tributary to Sevenmile River
Culvert Replacement Concept
Spencer, MA

Site Description

Water Street crosses an unnamed tributary to the Sevenmile River approximately 500 feet southeast of Route 9. The crossing's outlet consists of a 4-foot diameter, round concrete pipe. The inlet was unassessed, as the culvert is buried under an adjacent factory/warehouse building located at 1 Water Street. It was noted that rock and sediment are collapsing in on the structure; structural integrity of the barrel was therefore rated as critical and deformation was evident within the structure. The crossing severely constricts the channel's 15-foot bankfull width, and both a large scour pool and downstream sediment deposition were present. There is a freefall condition at the outlet. Hydraulic capacity could not be calculated due to the limited data available at this site. However, based on the partial information collected, it is anticipated that the existing crossing is undersized for the 10-year and larger peak flows, as well as for future climate conditions. Because of its location in Spencer's town center area, the crossing received one of the highest scores for flood impact potential.

Proposed Concept

- Due to the nature of the site, it is likely that the crossing would need to be replaced in conjunction with redevelopment of the site at 1 Water Street. If redevelopment were to occur, the Town should evaluate a stream re-alignment and/or daylighting project that allows the stream to flow at its full 15-foot bankfull width. The proposed replacement crossing should consist of an 18-foot span bridge or open-bottom arch to accommodate the 1.2 times bankfull width design standard of the Massachusetts River and Stream Crossing Standards.
- Reconstruct stream channel and banks to match existing upstream and downstream channel and banks, including stream substrate and slope
- The proposed culvert replacement concept will:
  - ➢ Provide increased hydraulic capacity
  - ➢ Eliminate a significant barrier to aquatic passage
  - ➢ Provide daylighted stream corridor/green space in town center area
  - ➢ Provide additional flood storage

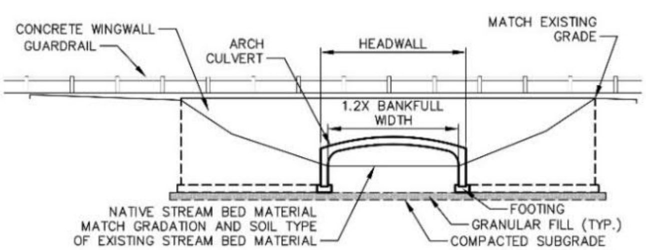


Image 3: Typical detail of an open arch culvert designed to meet MA Stream Crossing Standards.

Image 1: View of freefall condition at crossing outlet during field assessment on November 15, 2018.

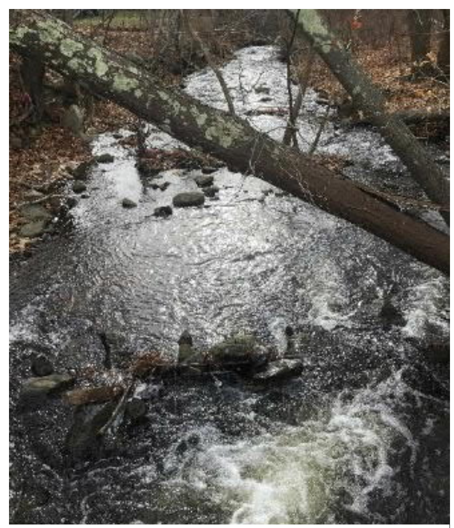


Image 2: Downstream channel on November 15, 2018.

Site Prioritization Summary
Scaled Crossing Priority Score (0-1): 0.87
Impact Score (1-5): 5
Hydraulic Risk Score (1-25): Not assessed
Geomorphic Risk Score (1-25): 15
Structural Risk Score (1-25): 25
AOP Benefit Score (1-25): 12

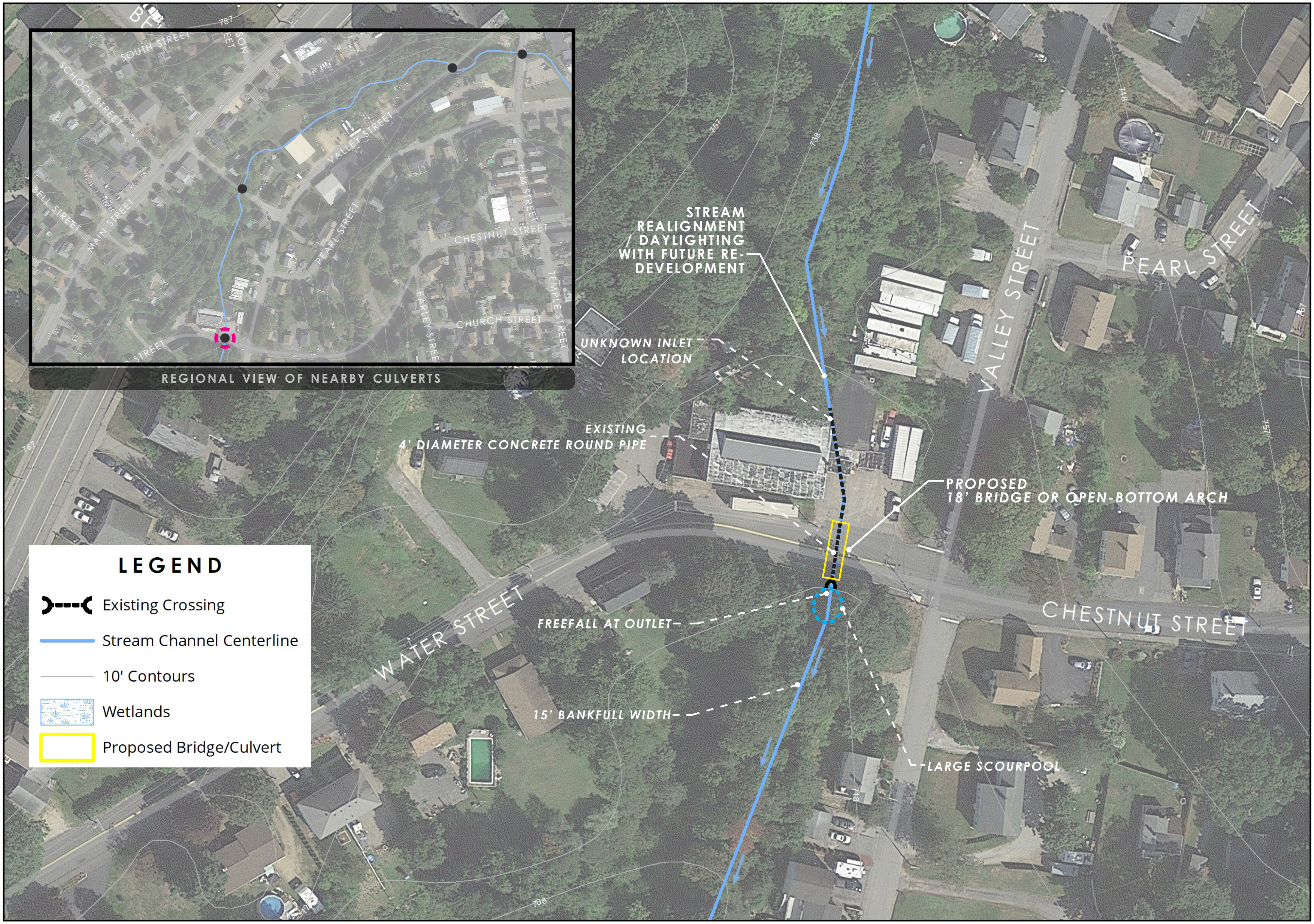
Existing Crossing Characteristics
Material: Concrete pipe
Structure Width: 4 feet
Structure Height: 4 feet
Structure Length: 120 feet (estimated with aerials)
Bankfull Width: 15 feet

Hydraulic Capacity Summary
Total Drainage Area: 1.8 miles^2
Existing Structure Capacity: Not calculated
Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	185 cfs	222 cfs
25-year	256 cfs	307 cfs
50-year	316 cfs	379 cfs
100-year	381 cfs	457 cfs

Notable Assessment Findings
Freefall at outlet
Culvert buried for substantial length
Severe constriction
High flood impact potential
Critical structural condition

Estimated Replacement Cost Range
Crossing replacement cost: $500K to $750KDoes not include daylighting/redevelopment costs



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Water Street, Spencer, MA

Culvert Replacement Concepts, Charlton & Spencer, MA

0 50 100 Feet

N S W E

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Mill Street at Unnamed Tributary to Sevenmile River
Culvert Replacement Concept
Spencer, MA

Site Description
Mill Street crosses an unnamed tributary to the Sevenmile River approximately 270 feet from Route 9, and 125 feet west of Valley Street. The crossing consists of a 4-foot diameter, round concrete pipe that severely constricts the channel's 10-foot bankfull width. A freefall onto cascade at the outlet, downstream scour pool, and high bank erosion along the channelized stream contribute to high geomorphic risk at this crossing. The channel banks have been armored with large rip rap in an attempt to control erosion. Hydraulically, the structure is undersized for all evaluated return interval peak flows, including the 10-year peak flow and is expected to become further undersized relative to future climate conditions. Because of its location in Spencer's densely developed town center area (and between adjacent high priority crossings both upstream and downstream), the crossing received one of the highest scores for flood impact potential across all assessed structures. There is a mapped FEMA 100-year flood zone located approximately 1,500 feet downstream of the crossing.

Proposed Concept
- Replace the existing undersized culvert with a 12-foot wide open-bottom arch to accommodate the 1.2 times bankfull width design standard of the Massachusetts River and Stream Crossing Standards.
- Reconstruct the stream channel and banks through the crossing to match the existing channel and banks, including stream substrate and slope.
- The proposed culvert replacement design concepts will:
  - Provide increased hydraulic capacity to accommodate peak flows and reduce risks from flooding
  - Reduce the potential for scour and erosion and associated geomorphic risk by reducing constriction

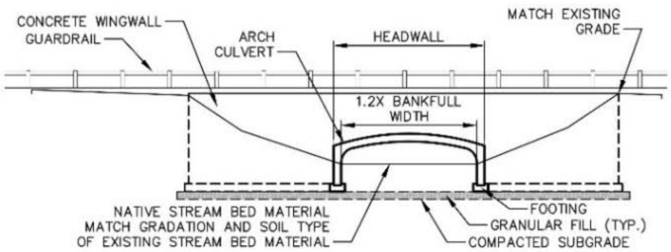

Image 4: Typical detail of an open arch culvert designed to meet MA Stream Crossing Standards.


Image 1: View of crossing inlet during field assessment on November 15, 2018.


Image 2: View of crossing outlet during field assessment on November 15, 2018.


Image 3: View of upstream channel on November 15, 2018.

Site Prioritization Summary
Scaled Crossing Priority Score (0-1): 0.84
Impact Score (1-5): 5
Hydraulic Risk Score (1-25) (Existing/Future): 25/25
Geomorphic Risk Score (1-25): 25
Structural Risk Score (1-25): 15
AOP Benefit Score (1-25): 9

Existing Crossing Characteristics
Material: concrete
Structure Width: 4 feet
Structure Height: 4 feet
Structure Length: 31feet
Bankfull Width: 10 feet

Hydraulic Capacity Summary
Total Drainage Area: 1.7 miles^2
Existing Structure Capacity: 104 cfs
Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	184 cfs	221 cfs
25-year	254 cfs	305 cfs
50-year	313 cfs	376 cfs
100-year	377 cfs	452 cfs

Notable Assessment Findings
Severe constriction
Freefall onto cascade at outlet
Large scour pool
High bank erosion
Undersized for all evaluated peak flows

Estimated Replacement Cost Range
Total project cost: $300K to $500K

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Mill Street, Spencer, MA

Culvert Replacement Concepts, Charlton & Spencer, MA

0 50 100 Feet

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May Street at Unnamed Tributary to Sevenmile River
Culvert Replacement Concept
Spencer, MA

Site Description

May Street crosses an unnamed tributary to the Sevenmile River mid-way between Cherry Street and Holmes Street, approximately 1,000 feet south of Route 9. The crossing consists of two corrugated metal pipes, one of 1.5-foot diameter, and a second pipe round pipe that had been crushed, yielding dimensions of 3-feet wide by 2-feet high. The combined 4.5-foot width of the two culverts is severely constricting relative to the bankfull width of the channel. A freefall is present at the outlet of the smaller pipe. There is an additional drainage pipe which empties into the smaller culvert inside the pipe; its origin could not be determined. A downstream scour pool, and sediment deposition both upstream and downstream of the crossing are indicative of high geomorphic risk. Hydraulically, the crossing is significantly undersized for all evaluated return interval peak flows. The peak flow estimates and hydraulic capacity analysis do not account for additional flows from the contributing storm drainage pipe. Because of its location in Spencer's densely developed town center area, the crossing received one of the highest scores for flood impact potential.

Proposed Concept

- Replace the existing undersized culvert with a 10-foot wide embedded box culvert to accommodate the 1.2 times bankfull width design standard of the Massachusetts River and Stream Crossing Standards.
- Reconstruct stream channel and banks through the crossing to match the existing channel and banks, including stream substrate and slope.
- Determine contributing drainage area for the drainage pipe that empties into the smaller of the two stream culverts and investigate green infrastructure opportunities to infiltrate or retain this water upstream.
- The proposed culvert replacement design concept will:
  - ➢ Provide increased hydraulic capacity
  - ➢ Reduce the potential for scour and erosion by reducing constriction
  - ➢ Reduce additional pressure on the crossing capacity from contributing drainage flows

Image 1: View of crossing outlet during field assessment on November 8, 2018.

Image 2: View of crossing inlet during field assessment on November 8, 2018.

Image 3: Example of embedded box culvert (Maine Audubon).

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.81
Impact Score (1-5): 5
Hydraulic Risk Score (1-25) (Existing/Future): 25/25
Geomorphic Risk Score (1-25): 20
Structural Risk Score (1-25): 10
AOP Benefit Score (1-25): 6

Existing Crossing Characteristics

Material: corrugated metal pipe
Structure Width: 1.5 feet, 3 feet
Structure Height: 1.5 feet, 2 feet
Structure Length: 42 feet
Bankfull Width: 8 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.4 miles^2
Existing Structure Capacity: 26 cfs
Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	74 cfs	89 cfs
25-year	104 cfs	125 cfs
50-year	130 cfs	156 cfs
100-year	158 cfs	190 cfs

Notable Assessment Findings

Deformation of larger metal pipe
Severe constriction
Additional drainage pipe present in smaller pipe
Undersized for all evaluated peak flows
Downstream scour pool and sediment

Estimated Replacement Cost Range

Total project cost: $250K to $400K

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May Street, Spencer, MA

Culvert Replacement Concepts, Charlton & Spencer, MA

0 50 100 Feet

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East Baylies Road at Unnamed Stream
Culvert Replacement Concept
Charlton, MA

Site Description

East Baylies Road crosses an unnamed stream just north of Saundersdale Road. The crossing consists of multiple materials; the inlet is a stone box culvert approximately 3 feet wide and 2.5 feet high, but the outlet is a single corrugated metal pipe of approximately 2 feet in diameter. Both the inlet and outlet are significantly narrower than the stream's approximately 11-foot bankfull width, resulting in severe constriction. There is a drop at the inlet due to a blockage that was rated as critical, and the outlet pipe is badly deteriorated and was rated as critical for invert condition, seam condition, crushing, and structural integrity. The crossing is sized to pass the 10-year peak flow, but is undersized for all other return intervals and for future climate conditions.

Proposed Concept

- Replace the existing undersized culvert with a 14-foot wide embedded box culvert to accommodate the 1.2 times bankfull width design standard of the Massachusetts River and Stream Crossing Standards. Reconstruct stream banks at the crossing to match the existing stream channel upstream and downstream of the crossing.
- The proposed culvert replacement design concept will:
  - ➢ Provide increased hydraulic capacity to reduce flooding risk
  - ➢ Improve hydraulic flow through the culvert by replacing the structure with one of uniform shape and material
  - ➢ Reduce potential for blockages and accumulated debris at the undersized inlet

Image 4: Example of embedded box culvert (Maine Audubon).

Image 1: View of structure outlet taken during field assessment on October 16, 2018.

Image 2: View of critical barrel and seam condition of the crossing outlet pipe on October 16, 2018.

Image 3: View of downstream channel, October 16, 2018.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.69
Impact Score (1-5): 4
Hydraulic Risk Score (1-25) (Existing/Future): 20/20
Geomorphic Risk Score (1-25): 12
Structural Risk Score (1-25): 20
AOP Benefit Score (1-25): 9

Existing Crossing Characteristics

Material: Stone (inlet), Corrugated Metal (outlet)
Structure Width: 3 feet (inlet) 2 feet (outlet)
Structure Height: 2.5 feet (inlet) 2 feet (outlet)
Structure Length: 42 feet
Bankfull Width: 11 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.05 $miles^2$
Existing Structure Capacity: 3.1 cfs
Estimated Peak Flows:

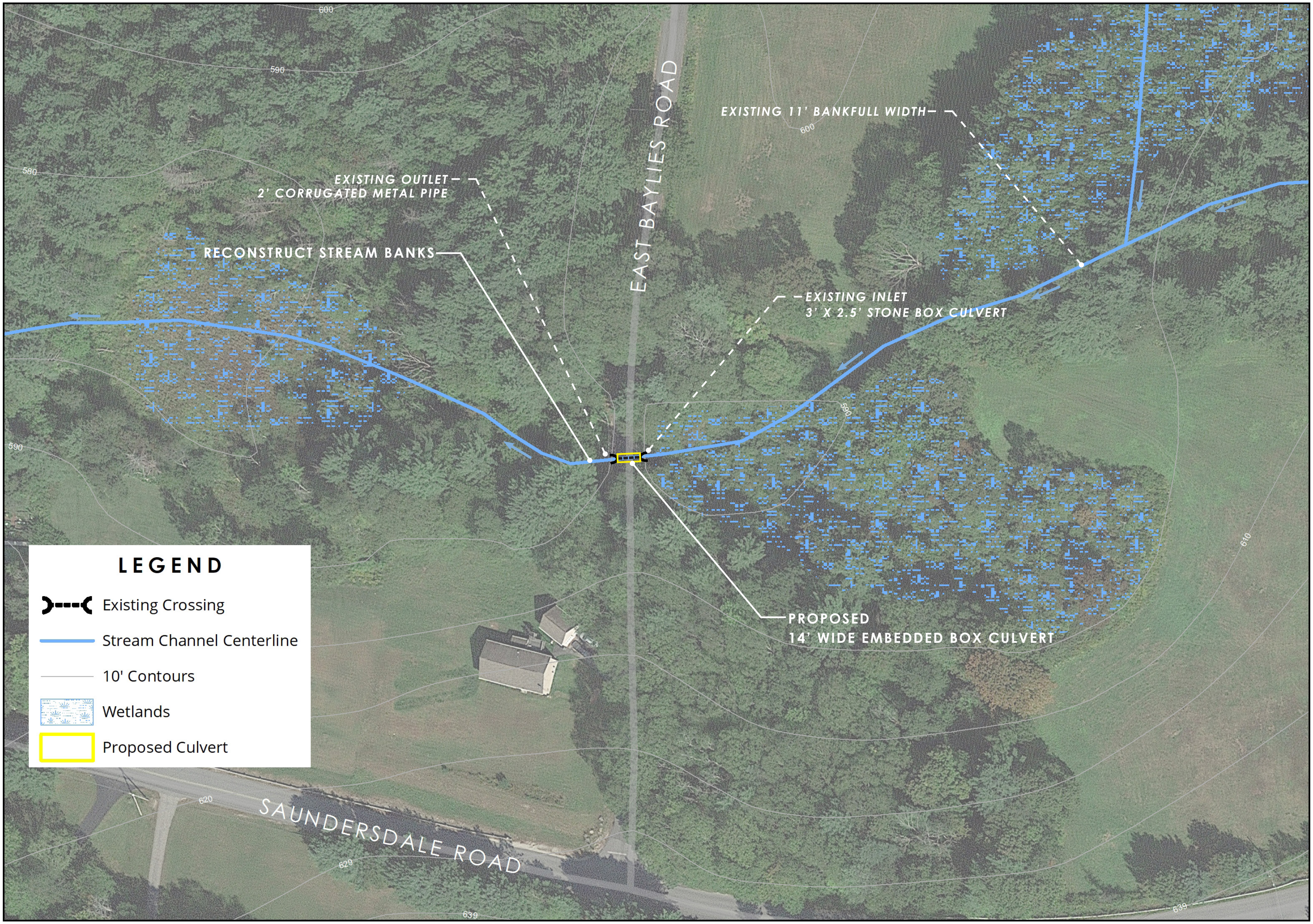
Recurrence Interval	Existing	Future
10-year	10 cfs	12 cfs
25-year	15 cfs	17 cfs
50-year	18 cfs	22 cfs
100-year	22 cfs	26 cfs

Notable Assessment Findings

Inlet drop
Severe constriction
Small scour poor
Critical deterioration of barrel at outlet
Sediment deposition upstream, within structure

Estimated Replacement Cost Range

Total project cost: $400K to $600K



East Baylies Road, Charlton, MA

Culvert Replacement Concepts, Charlton & Spencer, MA

0 50 100 Feet

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Stafford Street and Center Depot Road at Unnamed Stream
Culvert Replacement Concept
Charlton, MA

Site Description

Near the intersection of Stafford Street and Center Depot Road, an unnamed stream crosses each road at two locations within approximately 200 feet of one another. The Stafford Street structure is a 2.5 diameter corrugated metal pipe, while the Center Depot Road structure is a 2-foot diameter concrete pipe. The structure at Center Depot Road was completely submerged at the inlet and partially submerged at the outlet at the time of field assessment. Backwatering was noted at the Center Depot Road crossing due to the downstream Stafford Street crossing. Both structures are severely constricting the stream channel, which has resulted in the development of a large scour pool at the outlet of the Stafford Street structure. A freefall condition is also present at the outlet of the Stafford Street structure. Both structures are undersized for the 10-year peak flow under existing conditions, and are therefore also undersized for larger peak flows as well as expected increases in extreme flows under projected future climate conditions.

Proposed Concept

- Stafford Street:
  - ➢ Replace the existing undersized culvert with a 7.5-foot wide open-bottom arch
  - ➢ Realign crossing to better match existing stream channel alignment
  - ➢ Reconstruct stream banks and channel at and within the crossing to match existing stream channel up and downstream of the crossing
- Center Depot Road:
  - ➢ Replace the existing undersized culvert with a 7.5-foot wide embedded box culvert
- The proposed culvert replacement design concepts will:
  - ➢ Reduce geomorphic risk at the Stafford Street crossing
  - ➢ Protect Stafford Street crossing from outlet scour
  - ➢ Eliminate backwater condition at Center Depot Road crossing
  - ➢ Provide increased hydraulic capacity
  - ➢ Improve aquatic and terrestrial passage

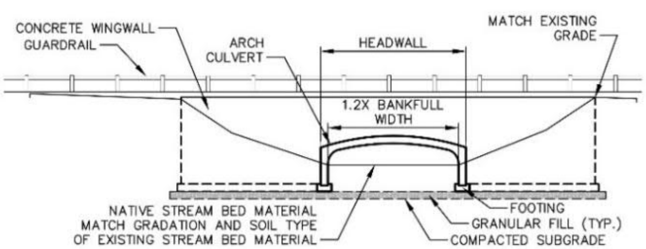


Image 4: Typical detail of an open arch culvert designed to meet MA Stream Crossing Standards.

Image 1: View of partially submerged outlet at crossing on Center Depot Road on October 31, 2018.

Image 2: View of crossing outlet at the Stafford Street crossing taken on October 29, 2018.

Image 3: View of backwater condition at the submerged inlet of the Center Depot Road crossing on October 31, 2018.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.69
Impact Score (1-5): 4
Hydraulic Risk Score (1-25) (Existing/Future): 20/20
Geomorphic Risk Score (1-25): 12 to 16
Structural Risk Score (1-25): 8
AOP Benefit Score (1-25): 9

Existing Crossing Characteristics

Material: corrugated metal pipe, concrete
Structure Width: 2 to 2.5 feet
Structure Height: 2 to 2.5 feet
Structure Length: 54 to 89 feet
Bankfull Width: 6 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.29 miles^2
Existing Structure Capacity: 20 to 24 cfs
Estimated Peak Flows:

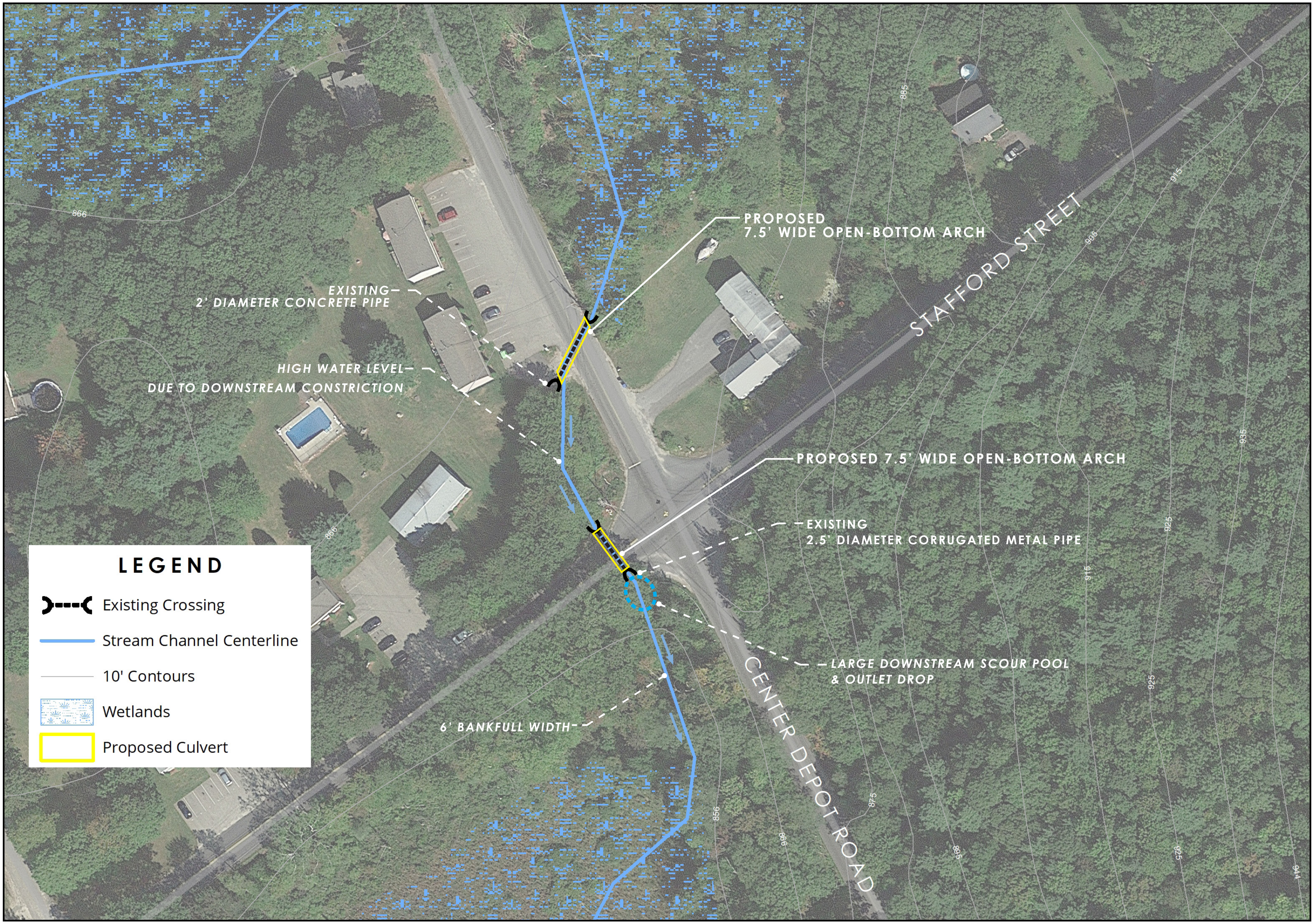
Recurrence Interval	Existing	Future
10-year	46 cfs	55 cfs
25-year	65 cfs	78 cfs
50-year	80 cfs	96 cfs
100-year	98 cfs	117 cfs

Notable Assessment Findings

Severe constriction
Large scour pool
Freefall at outlet
Undersized for 10-year peak flow
Backwatering noted

Estimated Replacement Cost Range

Total project cost (both sites): $400K to $500K



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Stafford Street & Center Depot Road, Charlton,MA

Culvert Replacement Concepts, Charlton & Spencer, MA

0 50 100 200 Feet

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Blood Road at Unnamed Stream
Culvert Replacement Concept
Charlton, MA

Site Description

Blood Road crosses an unnamed stream approximately 0.6 miles north of Saundersdale Road. The crossing consists of a single, 30-foot long, 1.5-foot diameter smooth plastic pipe. There is a small dam, approximately 2-feet in height, located 10-feet upstream of the crossing. Bankfull width could not be measured at this location due to the density of invasive multiflora rose on the downstream side of the crossing; however based on visual assessment, the degree of constriction was rated as moderate. The structure had both an inlet drop and a freefall condition at the outlet, with a drop of 1.2 feet from the pipe to the stream bottom. Structural condition was not a major concern at this crossing, but geomorphic risks were considered moderate, and the crossing was rated poorly for hydraulic capacity. The existing structure is undersized for the 10-year peak flow under existing conditions, and is therefore also undersized for larger peak flows as well as expected increases in extreme flows under projected future climate conditions.

Proposed Concept

- Evaluate removal of the upstream, non-jurisdictional dam and replace the existing undersized culvert with an embedded box culvert sized to accommodate the 1.2 times bankfull width design standard of the Massachusetts River and Stream Crossing Standards (based on available information, it is estimated that the structure will need to be approximately 4 feet wide).
- The proposed culvert replacement design concept will:
  - ➢ Provide increased hydraulic capacity to reduce risks from road overtopping
  - ➢ Reduce geomorphic risk associated with inlet drop and freefall conditions
  - ➢ Reduce risk of flooding associated with potential dam failure

Image 3: Example of embedded box culvert (Maine Audubon).

Image 1: View of crossing outlet taken during field assessment on October 16, 2018. Note the freefall condition which contributes to geomorphic risk.

Image 2: View of structure inlet taken during field assessment on October 16, 2018.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.69
Impact Score (1-5): 4
Hydraulic Risk Score (1-25) (Existing/Future): 20/20
Geomorphic Risk Score (1-25): 12
Structural Risk Score (1-25): 8
AOP Benefit Score (1-25): 9

Existing Crossing Characteristics

Material: Smooth Plastic
Structure Width: 1.5 feet
Structure Height: 1.5 feet
Structure Length: 30 feet
Bankfull Width: Could not be measured

Hydraulic Capacity Summary

Total Drainage Area: 0.04 miles^2
Existing Structure Capacity: 8.6 cfs
Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	10 cfs	12 cfs
25-year	14 cfs	16 cfs
50-year	17 cfs	20 cfs
100-year	21 cfs	25 cfs

Notable Assessment Findings

Inlet drop
Freefall at outlet
Moderate constriction
Small dam present upstream of crossing

Estimated Replacement Cost Range

Total project cost: $100K to $200K
(does not include dam removal)

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Blood Road, Charlton, MA

Culvert Replacement Concepts, Charlton & Spencer, MA

0 50 100 Feet

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Freeman Road at Unnamed Stream
Culvert Replacement Concept
Charlton, MA

Site Description

Freeman Road crosses an unnamed stream just south of Mugget Hill Road and approximately 600 feet from Wabash Pond. The crossing consists of a 2.5-foot wide, corrugated metal elliptical arch pipe set into a concrete headwall. The structure is severely constricting relative to the stream's 8-foot bankfull width. The constricted condition has led to the formation of a large downstream scour pool and deposition of sediment both upstream and downstream of the crossing. Structural condition was rated as adequate for all assessed features. The existing crossing is sized to pass the 10-year peak flow, but is undersized for larger peak flows and for future climate conditions.

Proposed Concept

- Replace the existing undersized culvert with a 10-foot wide embedded box culvert to accommodate the 1.2 times bankfull width design standard of the Massachusetts River and Stream Crossing Standards. Restore the stream banks and stream channel to repair scour.
- The proposed culvert replacement design concept will:
  - ➢ Provide increased hydraulic capacity to reduce risks of flooding
  - ➢ Reduce the potential for scour and erosion and associated geomorphic risk by reducing constriction
  - ➢ Improve hydrologic connectivity of the upstream and downstream ecosystems

Image 4: Example of embedded box culvert (Maine Audubon).

Image 1: View of crossing outlet and scour pool taken during field assessment on October 18, 2018.

Image 2: View of inlet, October 18, 2018.

Image 3: View of upstream channel (left) and downstream channel (right) on October 18, 2018.

Site Prioritization Summary

Scaled Crossing Priority Score (0-1): 0.69
Impact Score (1-5): 4
Hydraulic Risk Score (1-25) (Existing/Future): 16/20
Geomorphic Risk Score (1-25): 12
Structural Risk Score (1-25): 4
AOP Benefit Score (1-25): 9

Existing Crossing Characteristics

Material: Corrugated Metal Pipe
Structure Width: 2.5 feet
Structure Height: 2 feet
Structure Length: 46 feet
Bankfull Width: 8 feet

Hydraulic Capacity Summary

Total Drainage Area: 0.08 miles^2
Existing Structure Capacity: 19.5 cfs
Estimated Peak Flows:

Recurrence Interval	Existing	Future
10-year	19 cfs	23 cfs
25-year	27 cfs	32 cfs
50-year	34 cfs	40 cfs
100-year	41 cfs	49 cfs

Notable Assessment Findings

Severe constriction
Large scour poor
Sediment deposition upstream and downstream
Undersized for larger peak flows

Estimated Replacement Cost Range

Total project cost: $250K to $400K

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Freeman Road, Charlton, MA

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0 50 100 Feet

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Policy and Regulatory Recommendations

1. ***Incorporate priority stream crossings identified in this study into local hazard mitigation plans.***

   Communities with FEMA-approved hazard mitigation plans are eligible to apply for Hazard Mitigation Grant Program funding from FEMA for measures identified in their plans. Stream crossing upgrade priorities need to be included in these plans before floods occur. Vulnerable stream crossings identified in this watershed management plan and the accompanying *Road-Stream Crossing Assessment Technical Memorandum* in **Appendix B**, particularly crossings identified as high- and medium-priority, should be identified in the hazard mitigation plans of the both communities.

   The towns should update and integrate their comprehensive land use plans and hazard mitigation plans. Coordinating these two planning processes can ensure that stakeholders involved in resilience planning, such as emergency managers, also help develop the comprehensive plan and that planners help develop the hazard mitigation plan. Future updates to comprehensive land use plans and hazard mitigation plans of each community should include or incorporate by reference recommendations of the *Integrated Water Infrastructure Vulnerability Assessment and Climate Resiliency Plan*.

2. ***Update design storm precipitation amounts in local land use regulations and policies to promote more resilient road crossing design.***

   The Rainfall Frequency Atlas of the United States, also known as Technical Paper 40 (TP-40), published by the U.S. Department of Commerce, National Weather Service (formerly the U.S. Weather Bureau) in 1961, has served as the primary source of precipitation frequency estimates used in the design of storm drainage systems and other water infrastructure in the United States. The TP-40 estimates are based on a limited and outdated data set that extends over only an average of 40 years, with the most recent data ending in 1958. The TP-40 estimates do not account for the increases in precipitation that have been observed at many locations over the past 60 years since they do not include most current precipitation data. The TP-40 estimates can therefore underestimate precipitation and runoff, particularly in the face of a changing climate.

   Updated extreme precipitation data is available from Cornell University's Northeast Regional Climate Center (NRCC). The NRCC design storm rainfall amounts offer significant advantages over TP-40 since the design storm rainfall amounts are based on a much longer period of record, including more recent data. The most recent rainfall frequency statistics for the region were published by NOAA in October 2015 (revised 2019) in Atlas 14, Volume 10. This publication replaces TP-40 and supersedes the 2013 NRCC data products.

   While NOAA Atlas 14 provides more reliable precipitation data for design purposes, it assumes climatic stationarity and therefore does not account for future climate change. The Northeast Climate Science Center at the University of Massachusetts Amherst projects that, given a medium to high future emissions pathway, Charlton and Spencer will see as much as nine inches of additional rainfall per year by the end of the century. More critically in terms of flood potential, each town could see up to 4.5 additional days with precipitation over one inch, with the greatest increases occurring during the winter season, when partially frozen ground reduces infiltration and further exacerbates flooding risk. Communities should account for potential climate change (i.e., more frequent and intense precipitation) in drainage and flood mitigation design policies and standards. Additional guidance is available for estimating potential future changes in extreme rainfall statistics using EPA's Climate Resilience Evaluation and Awareness Tool (CREAT), SWMM-CAT (Storm Water Management Model Climate Adjustment Tool), and other similar tools.

At a minimum, stormwater and drainage-related infrastructure should be designed with storm intensities based on NOAA Atlas 14 (or NRCC atlas) to represent current precipitation conditions. For more resilient water infrastructure design, including improved stream crossings, consider designing for a 20% increase in design rainfall intensity, which is consistent with climate change projections for extreme precipitation under a medium to high emissions scenario and a 50- to 100-year planning horizon[3].

Note that both the Massachusetts Department of Environmental Protection and a separate Technical Advisory Committee are in the process of updating design storm intensities as part of anticipated revisions to the *Massachusetts Stormwater Handbook* and state wetland regulations. Current statewide guidance suggests that TP-40 values should continue to be used for calculating stormwater peak runoff rates, although the guidance also allows applicants and municipalities to use the NOAA Atlas 14 or NRCC approaches provided that the selected methodology has a higher precipitation value than that of TP-40 for the geographic location being evaluated. **The towns should revisit the recommendations relative to the revised design storm intensities that are expected to be issued as part of the updated *Massachusetts Stormwater Handbook* and state wetland regulations.**

3. ***Establish adequate, sustained sources of funding.***

With aging and vulnerable infrastructure in many places in both Spencer and Charlton, a sustained source of funding will be required to offset the higher initial cost of upgrading stream crossings, which can reduce future damages and save money in the long term. Funding for stream crossing upgrades is extremely limited, with local highway departments maintaining the majority of roads in both communities (with the exception of the Massachusetts Turnpike and Route 20) and carrying most of the financial burden for stream crossing improvements. In addition to FEMA post-disaster funding programs, other potential funding sources for crossing replacement include:

- Massachusetts Municipal Vulnerability Preparedness (MVP) Action Grant Program, which provides financial assistance to MVP-certified municipalities for implementation of climate adaptation and resilience projects.
- Massachusetts Department of Ecological Restoration Culvert Replacement Municipal Assistance Grant Program, which prioritizes culvert replacement projects with both public benefits (e.g., access to critical locations) and environmental benefits (e.g., aquatic connectivity),
- FEMA hazard mitigation assistance grant programs administered by the Massachusetts Emergency Management Agency,
- Cost-share programs in which government agencies provide a portion of the funding through grant programs (e.g., the Eastern Brook Trout Joint Venture and grant programs of the National Fish and Wildlife Foundation) and the local town responsible for the crossing covers the remaining amount,

[3] Projected increases for the northeast generally range from around 5% to 25% for the 2-year to 100-year storm events based on several sources of climate change projections: Boston Water and Sewer Commission climate adaptation planning; U.S. EPA Climate Resilience Evaluation and Awareness Tool; U.S. EPA Storm Water Management Model Climate Adjustment Tool; Downscaled Projections of Extreme Rainfall in New York State developed by the Northeast Regional Climate Center (NRCC) and the New York State Energy Research and Development Authority (NYSERDA); New York City Preliminary Climate Resiliency Design Guidelines.

4. ***Provide training to highway departments.***

Training is recommended for local highway departments, engineers, and contractors involved in stream crossing replacement. A number of stream crossing training programs have been developed throughout the region including:

- Division of Ecological Restoration Municipal Culvert Replacement Training
https://www.mass.gov/news/municipal-culvert-replacement-training

- UMass Amherst RiverSmart Communities
https://extension.umass.edu/riversmart/resources-municipalities

- Vermont's Rivers and Roads Training
http://floodready.vermont.gov/improve_infrastructure/roads_culverts#training

- U.S. Forest Service Workshops on Designing for Aquatic Organism Passage at Road-Stream Crossings
https://www.fs.fed.us/biology/education/workshops/aop/

- Maine's Stream Smart Road Crossing Workshops
http://maineaudubon.org/streamsmart/training-resources/

5. ***Implement ongoing inspection and maintenance programs.***

The towns should implement regular inspection and maintenance programs for local road-stream crossings. Vulnerable stream crossings should be inspected for debris removal and to check the structural integrity of the structure such as the headwalls and pipe. Public works staff should also inspect and remove existing debris from vulnerable road-stream crossings prior to an anticipated flood event.

5.2 Dams and Impoundments

Adaptation Goal: Reduce the flood hazards posed by dams, and restore stream connectivity for fish and other aquatic organisms.

Recommended Adaptation Measures

Table 5-3 provides a summary of recommended site-specific and policy/regulatory adaptation measures relative to dams and their associated impoundments. Site-specific recommendations and additional discussion of the policy and regulatory recommendations follow the table.

Table 5-3. Adaptation recommendations for dams and impoundments.

Adaptation Measure	Lead Entity	Timeframe	Estimated Cost	Possible Funding Sources
Site-Specific Recommendations				
1. Conduct site-specific feasibility studies to further evaluate potential for dam removal, as well as other management options.	Charlton and Spencer, Dam Owners, local stakeholder groups	2-5 years	$$$ to $$$$	Cost-share grants (NOAA, USFWS, NFWF), MVP Action Grants, municipal funds
2. Obtain funding for and implement dam removal projects and other management recommendations.	Charlton and Spencer, Dam Owners, local stakeholder groups	2-10+ years	$$$$$	Cost-share grants (NOAA, USFWS, NFWF), MVP Action Grants, municipal funds
Policy and Regulatory Recommendations				
1. Incorporate priority recommendations identified in this study into local hazard mitigation planning documents.	Charlton and Spencer	1-2 years	$	Municipal funds

$ = $0 to $5,000 $$ = $5,000 to $10,000 $$$ = $10,000 to $50,000 $$$$ = $50,000 to $100,000
$$$$$ = Greater than $100,000

Site-Specific Recommendations

The evaluation described in the *Dams Assessment Technical Memorandum* (**Appendix C**) consisted of an initial screening-level assessment to evaluate and guide the development of management recommendations for each dam, with the goal of improving flood resiliency and aquatic habitat, river continuity, and fish passage.

The screening-level recommendations, which are summarized in **Table 5-4** (Charlton) and **Table 5-5** (Spencer), are preliminary in nature and require more detailed, site-specific evaluation to adequately assess various management alternatives, potential flood resiliency and ecological benefits, and potential impacts. Detailed feasibility studies are required to support selection of a preferred alternative, as well as future planning, design, permitting, and funding requests for implementation of specific dam management recommendations.

1. ***Conduct site-specific feasibility studies to further evaluate the potential for dam removal, as well as other management options.***

   The Towns, working with private dam owners, state agencies, and local stakeholder groups, should secure initial funding for and conduct feasibility studies to further evaluate the potential for dam removal, as well as other management options, for specific priority dams identified in this resiliency plan.

   When considering the costs and benefits of dam removal, the environmental services that could be restored should be included in any benefit-cost analysis. In addition, the benefit-cost analysis of dam repair should include the lost environmental services, life-cycle operation and maintenance cost, capital reinvestment costs, and the cost of ultimately decommissioning the dam.

   The feasibility of removing a dam is dictated by many factors including current uses of the impoundment, cooperation of the owner, potential impacts to existing wetlands and habitat, and management of potentially contaminated sediments. A feasibility study is needed to inform the decision about how to manage a dam, including the feasibility of dam removal as well as other options.

The Benefits of Dam Removal

Some dams provide important societal benefits such as recreation, irrigation, infrastructure support, open water habitat, or cultural/historical value. Other dams no longer serve the function for which they were constructed, pose a safety risk, negatively affect the environment, are a liability to their owners, and require expensive ongoing maintenance. Dam removal can provide the following benefits:

Flood Resiliency and Public Safety

- Prevent damage to human life and property resulting from dam failure
- Reduce backwater flood hazards upstream of dammed impoundments

Environmental

- Restore natural river flow and sediment and debris transport and improve water quality
- Remove barriers to fish migration and passage of other aquatic organisms and wildlife

Economic

- Eliminate liability and ongoing maintenance costs borne by dam owners

Community

- Enhance fishing and recreational boating opportunities in a restored river
- Riverfront revitalization and improved aesthetic opportunities

2. ***Obtain funding for and implement dam removal projects, where determined technically feasible and acceptable by the community.***

   Upon completion of site-specific feasibility studies, the project proponent should proceed with the following steps where dam removal is determined to be technically feasible and acceptable by the community:

   - **Fundraising:** Develop a fundraising strategy and a list of potential grant sources, gather letters of support, and apply for funding (see funding sources listed in **Section 6** of this plan).

   - **Community Outreach:** Meet with abutters and stakeholders to review alternatives and seek to obtain local support for a preferred alternative.

- **Pre-Permitting Meetings:** Meet with local, state, and federal officials and regulators to clarify and confirm regulatory review requirements and any additional information requirements needed by the agencies.

- **Engineering Design:** Develop engineering design plans (modification or dam removal and stream restoration), project specifications, and Engineer's Cost Estimate for construction.

- **Permitting:** prepare and file regulatory permit applications, attend public hearings, and address public and agency comments and permitting considerations.

- **Construction:** Hire contractors, drawdown impoundment, address impoundment sediments as necessary, remove dam structure, restore stream channel, and revegetate impoundment.

- **Post-Removal Monitoring:** conduct monitoring of restoration area and habitat following construction.

The cost to remove a dam is highly site-specific and can range from tens of thousands of dollars up to several million dollars depending on a variety of factors including the size of the dam, management of potentially contaminated sediments, and the aerial extent of the upstream restoration. Most dam removal projects generally range from $100,000 to $1 million in total costs.

Dam Removal Feasibility Study

A dam removal feasibility study provides concept-level plans and quantitative information on environmental and engineering feasibility to make final decisions on the project approach and funding needs. A feasibility study should include the following elements, at a minimum:

- Background data and information gathering
- Determine current uses and legal rights associated with dam and impoundment
- Assess land ownership around the impoundment and dam
- Conduct site visit and planning meeting with project proponent, dam owner, local, state, and federal agencies
- Survey - topographic, dam, bathymetry, and property boundary – and base mapping
- Wetland resource delineation
- Habitat assessment, listed species
- Hydrologic and hydraulic analysis
- Scour analysis
- Aquatic organism passage analysis
- Recreational and cultural assessment
- Archaeological reconnaissance survey
- Channel and riparian restoration plan
- Sediment characterization (quantity and quality of sediment in impoundment) and sediment management plan
- Preliminary structure removal plan
- Alternatives evaluation
- Preliminary/conceptual design drawings
- Preliminary opinion of cost
- Identification of required permits
- Report or technical memorandum

Table 5-4. Dam management recommendations for the Town of Charlton.

Dam Name and ID Number	Stream Name	Hazard Class	Owner	Description	Recommendation	Priority
Lower Sibley Pond Dam MA00099	Ashworth Brook	Significant	Formerly Catherine C. Gauthier – Under Probate as of Spring 2019	The dam, which is in poor condition, is currently under probate. The impoundment does not appear to support any active uses. Removal of the dam would eliminate a risk to Route 20 and an active rail line located downstream of the dam.	**Consider Removal**	**High**
Wee Laddie Pond Dam MA01827	Little River	Significant	St. Mark Coptic Orthodox Church	The dam is currently in poor condition and is located immediately upstream of an undersized culvert under Gould Road. A beaver dam has been built at the spillway, elevating the impoundment and reducing available freeboard. Removal of the dam in coordination with reconstruction of the culvert would eliminate a threat to the road.	**Consider Removal**	**High**
Rail Road Pond Dam MA01830	Unnamed Tributary to Cady Brook	Significant	Town of Charlton and Alois C Hauk Jr. (15 Old Spencer Road)	The dam is currently in poor condition and the impoundment has no known use. The dam embankment supports Old Spencer Road. The Town would prefer to remove the dam while maintaining the alignment of Old Spencer Road.	**Consider Removal but maintain Old Spencer Road**	**High**
Power Station Dam	Cady Brook	Not Rated	Michael King (7 Power Station Road)	Unregistered former hydroelectric dam, now in unsafe condition. The dam is located directly upstream of Carpenter Mill Dam and downstream of Dams 3 and 4. Removal should be considered in conjunction with removal of these dams.	**Consider Removal**	**High**
Dam 3	Cady Brook	Not Rated	Roger W. Meservey (City Depot Road)	Unregistered former mill dam. The dam is located downstream of Dam 4 and upstream of an undersized culvert under Route 31, as well as the Power Station Dam and Carpenter Mill Dam. Removal should be considered in conjunction with removal of these dams.	**Consider Removal**	**High**
Dam 4	Cady Brook	Not Rated	City Depot Road Realty Trust	Unregistered former mill dam. The dam is located upstream of Route 31, as well as Dam 3, the Power Station Dam, and Carpenter Mill Dam. Removal should be considered in conjunction with removal of these dams.	**Consider Removal**	**High**
Carpenter Mill Pond Dam MA03428	Cady Brook	Not Rated	TDW Realty Inc. (Power Station Road) and/or Alan Fitts (South Sturbridge Road)	This non-jurisdictional former mill dam is located downstream of the Power Station Dam and Dams 3 and 4 and upstream of Route 20. The impoundment does not appear to support any active uses. Removal should be considered in conjunction with removal of these dams.	**Consider Removal**	**Medium**

Table 5-4. Dam management recommendations for the Town of Charlton.

Dam Name and ID Number	Stream Name	Hazard Class	Owner	Description	Recommendation	Priority
Glen Echo Dam **MA00101**	Cady Brook Headwaters	High	Town of Charlton	The dam impoundment is used for recreation and flood control and is in fair condition. The dam is in fair condition.	**Repair/Maintain**	**Medium**
Lambs Pond Dam **MA01829**	Unnamed Tributary to Cady Brook	Significant	Curtis Hill Estates, Inc.	The impoundment is used for recreation and the dam is in fair condition. However, a beaver dam has been built at the spillway, increasing the water level in the impoundment and decreasing freeboard. The beaver dam should be removed and the dam repaired. If the dam cannot be maintained by the owner, including removal of beaver dams and debris as needed, removal should be considered.	**Remove to increase stream continuity and to address beaver problems, or Repair and remove beaver debris**	**Medium**
Farm Pond Dam **MA01838**	Unnamed Tributary to South Charlton Reservoir	Not Rated	Frank A. and Donna Robert (141 Muggett Hill Road)	The impoundment is used for recreation and the dam is in fair condition. The ability of the owner to maintain the dam is unknown. Removal should be considered but more information is needed to make a final decision.	**Consider removal. More information Needed.**	**Medium**
Little Nugget Lake Dam **MA00103**	Little Nugget Brook	Significant	Town of Charlton.	The dam is in good condition and the impoundment is used for recreation. The construction of a fishway could help improve aquatic connectivity and ecological health in Little Nugget Brook.	**Consider Adding AOP Facilities**	**Low**
Ashworth Dam **MA00100**	Ashworth Brook	Significant	Orrin J. Sisco (38 North Sullivan Road)	The condition and current use of the dam is unknown. If the dam has no present use, removal should be considered to reduce the risk to Interstate 90, Lower Sibley Pond Dam, Route 20, and other infrastructure located directly downstream of the dam in the event that Ashworth Dam should fail.	**Consider Removal or No Action**	**Unknown**
McIntyre's Pond Dam **MA01835**	Deans Brook headwaters	Not Rated	Thaddeus Mroczkowski (60 McIntyre Road)	The condition and current use of the dam is unknown. If the dam has no present use, removal should be considered to reduce the risk to private homes should McIntyre's Pond Dam fail.	**Consider Removal. More Information Needed.**	**Unknown**

Table 5-5. Dam management recommendations for the Town of Spencer.

Dam Name (Town)	Stream Name	Hazard Class	Owner	Description	Recommendation	Priority
Cranberry Meadow Pond Dam **MA00700**	Cranberry River	Significant	Donna Aucoin (Jolicoeur Avenue), Tina Lynn Ghelli and Simon Tesfaye (5 Joliqoeur Avenue), and/or Duane Carter and Paul L. Champoux (Cranberry Meadow Road). No dam owner recorded in Dam Safety records	The impoundment is used for recreation and the dam is in poor condition. The dam is located upstream of Cranberry Meadow Road. Multiple repairs are required at the dam.	**Repair**	**High**
Buck Hill Conservation Dam **MA00901**	Sevenmile River	Significant	Worcester County 4-H Center, Inc.	The impoundment is used for recreation and the dam is in fair condition. However, a beaver dam has been built at the spillway, increasing the water level in the impoundment and decreasing freeboard. The beaver dam should be removed and the dam repaired. The outlet condition should also be investigated to determine the cause of a "boil" observed at the toe of the dam. The feasibility of installing a structure for fish passage should be determined.	**Repair; Consider Adding AOP Facilities**	**High**
Muzzy Meadow Dam **MA02379**	Town of Spencer	High	Town of Spencer	The dam is in fair condition and the Town of Spencer anticipates improving aesthetics in the area, establishing walking trails around the impoundment, and utilizing the impoundment as a skating pond in the future.	**No Action**	**Medium**
Moose Hill Pond Dam **MA02583**	Shaw Brook	High	Massachusetts Department of Conservation and Recreation	The dam is in satisfactory condition and the impoundment is used for flood control and as an emergency water supply. Trails around the edge of the impoundment provide recreational opportunities. The feasibility of adding aquatic passage facilities to the dam should be investigated, although these facilities may be costly and difficult to install due to the size of the dam.	**Consider Adding AOP Facilities**	**Medium /Low**
Lake Whittemore Dam **MA00699**	Unnamed tributary of the Severn Mile River	High	Dam located on the property of Robert L Hassett Jr. (54 Highland Street) and Delana A Frigon, Lucille M LE Ellen Anderson, Trustee (56 Highland Street, Spencer). Dam is maintained by Town of Spencer DPW but the Town does not acknowledge ownership. Dam Safety records indicate the dam is owned by the Worcester County Electric Company	The impoundment is used for recreation and the dam is in satisfactory condition.	**No Action**	**Medium /Low**

Table 5-5. Dam management recommendations for the Town of Spencer.

Dam Name (Town)	Stream Name	Hazard Class	Owner	Description	Recommendation	Priority
Sugden Reservoir Dam **MA00698**	Shaw Brook	High	Town of Spencer	The dam is in fair condition and the impoundment is used for flood control and as an emergency water supply.	**Consider modifying to allow drawdown for additional flood capacity; Consider Adding AOP Facilities**	**Medium**
Howe Mill Pond Dam **MA01175**	Cranberry River	Significant	Massachusetts Department of Conservation and Recreation	The dam is in fair condition and is an aesthetic and cultural landmark within Howe State Park. The impoundment supports recreation. Repairs are recommended to maintain the dam in good condition, as it is located directly upstream of Howe Road	**Repair**	**Medium**
Howe Reservoir Dam **MA02542**	Cranberry River	Significant	Massachusetts Department of Conservation and Recreation	The dam and impoundment currently have no known use. The dam is in fair condition and beaver activity was observed at the spillway. The dam is located approximately 1000 feet upstream of Howe Mill Pond Dam and would therefore threaten Howe Mill Pond Dam and Howe Road if it were to fail.	**Consider removal to improve aquatic connectivity and remove a risk to Howe Mill Pond Dam (should Howe Reservoir Dam fail)**	**Medium**
Browning Pond Dam **MA00695**	Sevenmile River	Significant	Horn Archie Boy Scouts Additional entities with property on the dam include James R. Cobill (75 Browning Pond Road) and the Town of Spencer (Browning Pond Road)	This significant hazard dam impounds an impoundment used for recreational purposes; however, the impoundment was likely already a large pond prior to construction of the dam. The dam is in good condition, but the outlet, which consists of a culvert beneath Browning Pond Road, is undersized and is therefore typically submerged and impassable for some aquatic species. Removal of the dam could consist of removing a portion of the embankment and replacing the single culvert with one or more larger culverts to allow greater aquatic connectivity between the pond and the downstream wetlands, and to reduce the risk of washing out Browning Pond Road.	**Consider removal (in a manner that maintains Browning Pond Road) or Repair and add AOP facilities.**	**Low**
Lac Marie Dam **MA01997**	Sevenmile River	Significant	Cistercian Abbey of Spencer, Inc. (a.k.a. St. Joseph's Abbey)	The dam is in good condition and retains an impoundment for recreational purposes. High quality habitat is present upstream and downstream of the dam, but the dam presents a barrier to aquatic passage. Although space is limited, the construction of a fishway could help improve aquatic connectivity and ecological health in the Sevenmile River.	**Consider adding a fishway, although space is limited.**	**Low**
Cedar Mill Pond Dam (a.k.a. Cider Mill Pond Dam) **MA01995**	Unnamed tributary of the Severn Mile River	Not Rated	Mayan Tov, LLC.	The dam has been buried beneath the parking lot of the adjacent shopping center and was not accessible for assessment.	**More information needed.**	**Low**

Policy and Regulatory Recommendations

1. ***Incorporate priority dam management recommendations identified in this study into local hazard mitigation planning documents.***

   Charlton and Spencer have FEMA-approved hazard mitigation plans are therefore eligible to apply for Hazard Mitigation Assistance Grant Program funding for measures identified in their hazard mitigation plans. Identified dam management recommendations need to be identified in these plans before floods occur. Priority dam removal and repair recommendations identified in this plan and the accompanying *Dams Assessment Technical Memorandum* in **Appendix C**, particularly high- and medium-priority recommendations, should be included or referenced in the hazard mitigation plans of both communities.

5.3 Water and Wastewater Infrastructure

Adaptation Goal: Reduce the vulnerability of public drinking water wells, water distribution systems, wastewater collection systems, and wastewater treatment facilities to the impacts of flooding.

Recommended Adaptation Measures

Table 5-6 provides a summary of recommended site-specific and policy/regulatory adaptation measures for the water and wastewater infrastructure in both communities.

Table 5-6. Adaptation recommendations for water and wastewater infrastructure.

Adaptation Measure	Lead Entity	Timeframe	Estimated Cost	Possible Funding Sources
Site-Specific Recommendations				
1. Implement site-specific water and wastewater infrastructure upgrades identified in this study.	Charlton and Spencer	5-10+ years and as opportunities arise	$$$ (per project)	MVP Action Grants, , FEMA flood hazard mitigation assistance funding, State Revolving Fund (SRF) Loans, municipal funds
Policy and Regulatory Recommendations				
1. Adhere to climate resilience design criteria contained in accepted industry guidelines for the design of new facilities or upgrade/expansion of existing facilities.	Charlton and Spencer	Ongoing	Varies	MVP Action Grants, , FEMA flood hazard mitigation assistance funding, State Revolving Fund (SRF) Loans, municipal funds

$ = $0 to $5,000 $$ = $5,000 to $10,000 $$$ = $10,000 to $50,000 $$$$ = $50,000 to $100,000
$$$$$ = Greater than $100,000

Site-Specific Recommendations

1. Implement site-specific water and wastewater infrastructure upgrades identified in this study.

Adaptation recommendations were developed for each of the vulnerable facilities identified in both towns. These recommendations, which are summarized in **Table 5-7**, are intended to increase the facilities' flood resilience and protect critical equipment under existing and future climate conditions. Further details of the recommended adaptation measures for each facility are provided in the *Water and Wastewater Infrastructure Assessment Technical Memorandum* (**Appendix D**).

Table 5-7. Site-specific water and wastewater infrastructure adaptation recommendations.

Facility Name	Recommendations	Estimated Cost[1]
	Town of Charlton	
Old Worcester Road Pump Station	- Build a four-foot barrier with entrance access around the station to minimize floodwater	$34,000
North Main Street Pump Station	- Build a four-foot barrier with entrance access around the station to minimize floodwater	$34,000
Muggett Hill Road Pump Station	- Provide drainage swales to guide runoff and floodwaters away from the structures - Raise electrical equipment	$31,750
South Sturbridge Road Pump Station	- Provide drainage swales to guide runoff and floodwaters away from the structures and raise the electrical equipment	$25,000
Stevens Park Road Pump Station	- Redirect runoff from the hill to the north of the station - Guide street runoff from the road east of the station - Re-set the electrical panel on a new concrete pad and the ventilation system on a new concrete pad on a higher elevation - Re-set fencing - Grading improvements to accommodate new drainage work - Install drainage swales to improve water quality	$61,000
Route 20 (MTA 5E) Pump Station	- Provide a protective barrier for the main entrance to prevent water from entering the building - Install a watertight hatch over the access entrance to the level of the facility - Seal penetrations between main and lower levels (conduits and ventilation)	$30,000
J Hammond Road (MTA 6W) Pump Station		$45,000
Pressure Regulating Vault	- Re-direct runoff in the area - Modify the vault structure to minimize water and groundwater inflow	$33,500
	Town of Spencer	
Sevenmile River Wellfield	- Raise the electrical equipment that provide power and control for the well to a higher elevation	$10,000
Cranberry Wellfield	- Place a barrier at the door to minimize water getting into the building - Raise the main transformer just outside the well - Raise the distribution box for power and control in the storage building	$45,000
Wastewater Pump Station on Meadow Road	- Raise the existing generator and propane tank outside the facility to a higher elevation - Provide a barrier at the entrance of the facility to protect critical components that are less than three feet above the floor	$40,000
UV Disinfection System at the Discharge of the Wastewater Treatment Facility	- Install barriers around the UV channel and equipment to raise wall elevations three feet to protect the equipment and minimize the runoff going through the equipment during considerations for relocating the facility	$20,000
Low Lying Area off Adams Street Near Spencer Pond	- Further analyze the outlet structure to determine if it is properly sized and if the gates are operational - Install a level transducer to monitor waste levels and alert system operators if water levels are getting high	$32,500

[1]Excludes contractor general requirements (e.g., bonds, insurance, permits, and general conditions) and contingency.

For Charlton, the total cost of the proposed improvements is an estimated $379,000 to $579,000, which includes the estimated costs listed in **Table 5-7**, as well as contractor general requirements (e.g., building permits, builders risk insurance, and contractor bonds) and 25% contingency. Similarly, for Spencer, the total cost of the proposed improvements is an estimated $190,000 to $290,000, including contractor general requirements and contingency.

Policy and Regulatory Recommendations

1. ***Adhere to climate resilience design criteria contained in accepted industry guidelines for the design of new facilities or upgrade/expansion of existing facilities.***

The site-specific recommendations described above are for upgrades to existing vulnerable water and wastewater facilities in Charlton and Spencer. Both communities should adopt and adhere to climate resilience design criteria contained in the following industry-standard design guidelines for water and wastewater infrastructure in Massachusetts:

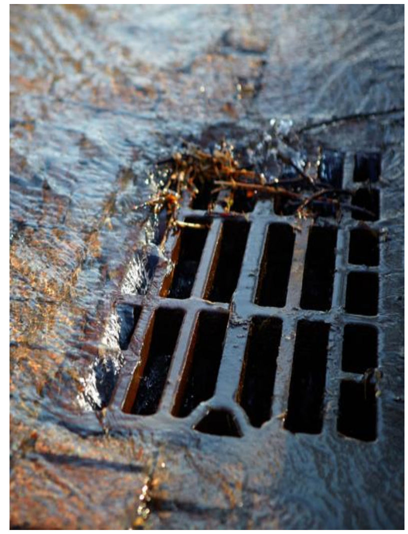
- **New England Interstate Water Pollution Control Commission (NEIWPCC) *TR-16 Guides for the Design of Wastewater Treatment Works*:** This is the primary design reference for wastewater treatment facilities in New England. TR-16 was revised in 2016 to address resiliency and adaptation considerations for extreme storm events.

- **Massachusetts Department of Environmental Protection (MassDEP) Guidelines for Public Water Systems (revised 2014):** These drinking water design guidelines are modeled after guidance used in other parts of the country and incorporate materials from other national organizations such as the American Water Works Association and U.S. Environmental Protection Agency, including *EPA's Climate Resilient Water Utilities* initiative for water infrastructure.

If new or expanded water or wastewater facilities are proposed in either community, including water or sewer extensions, the project site or area should be evaluated for vulnerability to flooding using LIDAR and FEMA flood hazard mapping (as described in the vulnerability assessment presented in this study), and the project designs should be consistent with the above guidelines to the maximum extent possible.

5.3 Stormwater Infrastructure

Adaptation Goal: Implement green infrastructure to reduce stormwater runoff volumes and peak discharges, drainage-related flooding, and pollutant discharges to receiving waters.



Recommended Adaptation Measures

Table 5-8 provides a summary of recommended site-specific and policy/regulatory adaptation measures related to stormwater and green infrastructure in both communities.

Table 5-8. Adaptation recommendations for stormwater and green infrastructure.

Adaptation Measure	Lead Entity	Timeframe	Estimated Cost	Possible Funding Sources
Site-Specific Recommendations				
1. Incorporate green infrastructure into municipal stormwater infrastructure planning and capital projects, and implement identified retrofit projects.	Charlton and Spencer	5-10+ years	$$$$$	319 NPS Grant, CDBG, Stormwater Utility, municipal funds
Policy and Regulatory Recommendations				
1. Review and update existing municipal land use regulations and policy to require the use of green infrastructure and LID for new development and redevelopment projects and to meet MS4 Permit requirements.	Charlton and Spencer, Central MA Regional Stormwater Coalition (CMRSWC)	2-5 years	$$	Municipal and CMRSWC funds
2. Update design storm precipitation amounts in local land use regulations and policies to promote more resilient stormwater drainage design.	Charlton and Spencer, Central MA Regional Stormwater Coalition	2-5 years	$$	Municipal and CMRSWC funds
3. Pursue sustainable, long-term funding sources for larger-scale GI implementation.	Charlton and Spencer, Central MA Regional Stormwater Coalition, CMRPC	5-10 years	$$$$	Stormwater utility district, enterprise fund, or similar fee-based system

$ = $0 to $5,000 $$ = $5,000 to $10,000 $$$ = $10,000 to $50,000 $$$$ = $50,000 to $100,000
$$$$$ = greater than $100,000

Site-Specific Recommendations

1. ***Incorporate green infrastructure into municipal stormwater infrastructure planning and capital projects, and implement identified retrofit projects.***

   The Towns should incorporate green infrastructure approaches into municipal stormwater infrastructure planning and capital improvement plans to address drainage, flooding, and water quality priorities including MS4 Permit requirements. Green infrastructure retrofits can be implemented on public sites including existing municipal parking lots using techniques such as bioretention, permeable pavement, and subsurface infiltration, as well as within the public right-of-way through the use of roadside bioswales, subsurface infiltration below roads and sidewalks, infiltrating catch basins, permeable pavement, and tree boxes.

   The green infrastructure retrofit concepts presented in *Green Infrastructure Assessment Technical Memorandum* (see **Appendix E**) provide potential on-the-ground projects for future implementation. They also serve as examples of the types of projects that could be implemented at other similar locations in both communities.

   Table 5-9 lists proposed green infrastructure retrofit concepts that have been developed for the Town of Charlton and the Town of Spencer, followed by concept design summaries for 10 of the assessed sites. The concept summaries include a site description, the proposed retrofit concept, field images and/or renderings of retrofit opportunities, typical details of recommended practices, and planning-level cost estimates (see **Appendix E**).

Table 5-9. Proposed green infrastructure retrofit locations.

Site No.	Site Name	Location	Green Infrastructure Practice Type
		Town of Charlton	
1	Charlton Police Department	Main Street, Charlton	Sand Filter, Vortex Separator
2	Charlton Municipal Offices (Town Hall)	Dresser Hill Road/Route 31, Charlton	Bioretention, Roof Runoff Capture and Reuse for Community Gardens
4	**Heritage School**	**Oxford Road, Charlton**	**Bioretention, Roof Runoff Capture and Reuse for Student Gardens, Regrade and Consider Elevating Heritage Road**
5	**Charlton Middle School**	**Oxford Road, Charlton**	**Green Roof, Bioretention, Roof Runoff Capture and Reuse for Student Gardens,**
6	Charlton Little League	Bond Road, Charlton	Bioretention
7	**Prindle Lake Park**	**Prindle Hill Road, Charlton**	**Bioretention**
10	Fields behind the Charlton Public Library	Main Street, Charlton	Bioretention
11	**Charlton Elementary School**	**Burlingame Road, Charlton**	**Bioretention, Underground Infiltration**
14	United States Post office	Power Station Road, Charlton	Bioretention
17	**Maynard Farms Recreation Area**	**Dresser Hill Road/Route 31, Charlton**	**Bioretention**

Table 5-9. Proposed green infrastructure retrofit locations.

Site No.	Site Name	Location	Green Infrastructure Practice Type
		Town of Spencer	
18	**Howe State Park**	**Howe Road, Spencer**	**Bioretention, Pavement Removal**
19	David Prouty High School and Spencer-East Brookfield Regional High School Athletic Fields	Main Street, Spencer	Bioretention, Roadside Swales
20	**Spencer Town Hall**	**Main Street, Spencer**	**Bioretention, Pavement Removal, Improved Pedestrian Access**
21	Powder Mill Park	Meadow Road, Spencer	Bioretention
23	**Richard Sugden Library**	**Main Street, Spencer**	**Bioretention**
25	Spencer Fairgrounds	Smithville Road, Spencer	Bioretention, Riparian Buffer
26	**O'Gara Park**	**Valley Street, Spencer**	**Riparian Buffer**
27	Knox Trail Junior High School	Ash Street, Spencer	Bioretention, Roof Runoff Capture and Reuse for Irrigation
29	Lake Street School (public amenity portion)	Lake Street and Highland Avenue, Spencer	Pavement Removal, Bioretention
30	Wire Village School	Paxton Road, Spencer	Bioretention, Roof Runoff Capture and Reuse for Irrigation
31	Intersection of Lloyd Dyer and Wall Streets	Wall Street and Lloyd Dyer Street, Spencer	Green Street
33	**Mechanic Street Parking Lot**	**Mechanic Street, Spencer**	**Bioretention, Underground Infiltration, Permeable Pavers**

Note: Concepts were developed for sites in bold.

Site 1 – Heritage School
Bioretention, Water Reuse for Irrigation, and Elevation of Access Road
Oxford Road, Charlton, Massachusetts

Site Description
The proposed retrofits are located at the Heritage School on Oxford Road. Runoff from the parking lots is currently drained via catch basins into low areas surrounding the school, which may include wetland areas. The area surrounding the school eventually drains into the South Charlton Reservoir. The western access road (Heritage Drive) drops in elevation as it passes through the surrounding low areas and is a known location for repeat flooding.

At the time of the site visit in December 2018, the school anticipated switching its water supply from an on-site well to municipal water within 6 months. Irrigation is not currently used but is desired to maintain a field at the rear of the school. A greenhouse and raised garden beds are located at the rear of the school for use by students.

Proposed Concept
- Install bioretention basins in the existing landscape islands in the main parking lot to filter water before it enters the wetland complex.
- Regrade and consider elevating Heritage Drive between the Heritage School and the turn off to Charlton Middle School to reduce the risk of flooding.
- Capture runoff from the roof for irrigation of fields and the greenhouse and raised beds, to reduce use of treated town water for irrigation.
- Install educational signage to inform students and visitors about the function and benefits of green stormwater infrastructure and low impact development.
- Incorporate stormwater concepts into the school's curriculum, using the proposed retrofits as real-world examples and sites for hands-on learning.

Image 1: Example of an established bioretention basin with a concrete curb cut and concrete pretreatment structure to remove sediment before runoff enters the planted portion of the basin.

Bioretention Concept Summary

Total Impervious Area: 2.2 acres

Treated Water Quality Volume: 8,100 ft^3

Estimated Cost

Bioretention Area: $208,000

Elevation of Access Road: $305,000

- Cost savings may be achieved in road is regraded when the new water main is installed along Heritage Drive

Water Reuse for Irrigation: cost not calculated

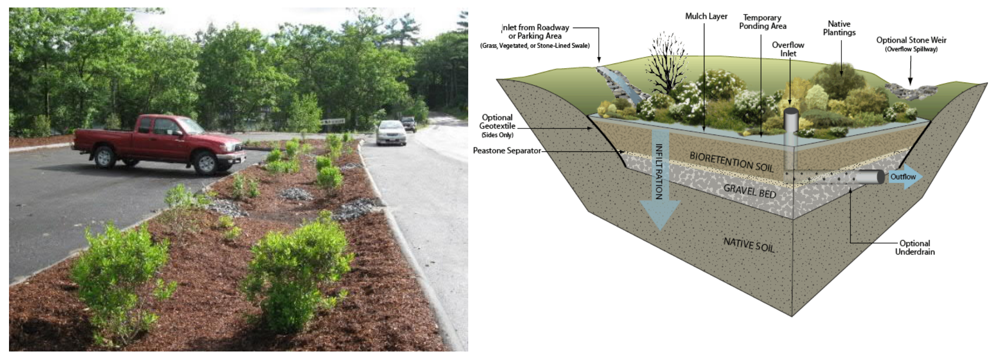


Image 2: Typical parking lot with bioretention and diagram of a bioretention basin. Image source: MA Clean Water Toolkit.

Image 3: Portion of access road to be regraded and potentially elevated.

Image 4: Greenhouse and raised garden beds at the rear of the school that could be irrigated using captured roof runoff.

Heritage School, Charlton, MA

Site Number: 1 May 2019

0 75 150 300 Feet

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Site 2 – Charlton Middle School
Green Roof, Bioretention, and Water Reuse for Irrigation
Oxford Road, Charlton, Massachusetts

Site Description
The proposed retrofits are located at the Charlton Middle School on Oxford Road. Much of the site's runoff is treated by existing stormwater treatment basins, which are fenced off for safety. However, runoff from one parking lot south of the school, which provides parking for the athletic fields, drains via catch basins directly into a wetland complex that feeds into the South Charlton Reservoir. In addition, the school roof is in poor condition, resulting in frequent leaks into the building and requiring frequent patching.

At the time of the site visit in December 2018, the school anticipated switching its water supply from an on-site well to municipal water within 6 months. Irrigation is currently supplied to plantings in the front of the building. A greenhouse and raised garden beds are located at the rear of the school for use by students.

Proposed Concept
- Install a bioretention basin along the western edge of the south parking lot to capture runoff before it enters the wetland complex. Construct the western embankment of the bioretention basin as a level spreader to evenly distribute rather than concentrate overflows.
- Replace the school roof and install an "extensive" type green roof on the front portion of the school building, above the main entrance.
- Capture runoff from the remaining portion of the roof for use in irrigation of landscape plantings and the greenhouse and raised beds, to reduce use of treated town water for irrigation
- Install educational signage to inform students and visitors about the function and benefits of green stormwater infrastructure and low impact development.
- Incorporate stormwater concepts into the school's curriculum, using the proposed retrofits as real-world examples and sites for hands-on learning.


Image 1: Typical installation of green roof system. Image © Green Roof Service LLC

Bioretention Concept Summary
Total Impervious Area: 1.6 acres
Treated Water Quality Volume: 5,700 ft^3

Estimated Cost
Green Roof: $328,000
Bioretention Area: $98,000
Water Reuse for Irrigation: cost not calculated

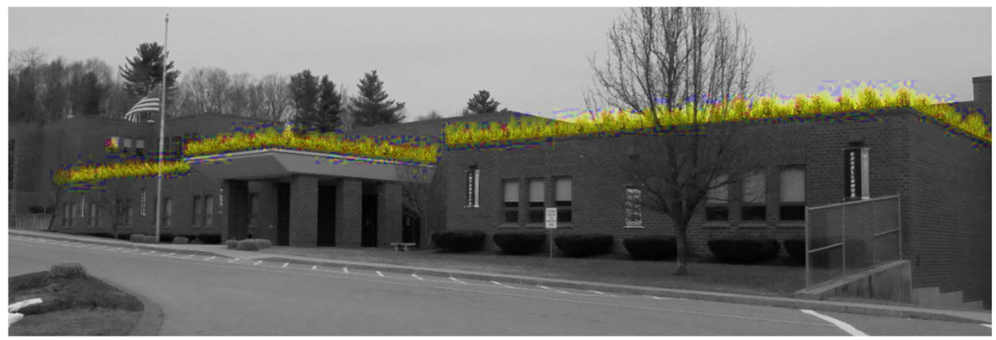


Image 2: Green roof rendering of Charlton Middle School

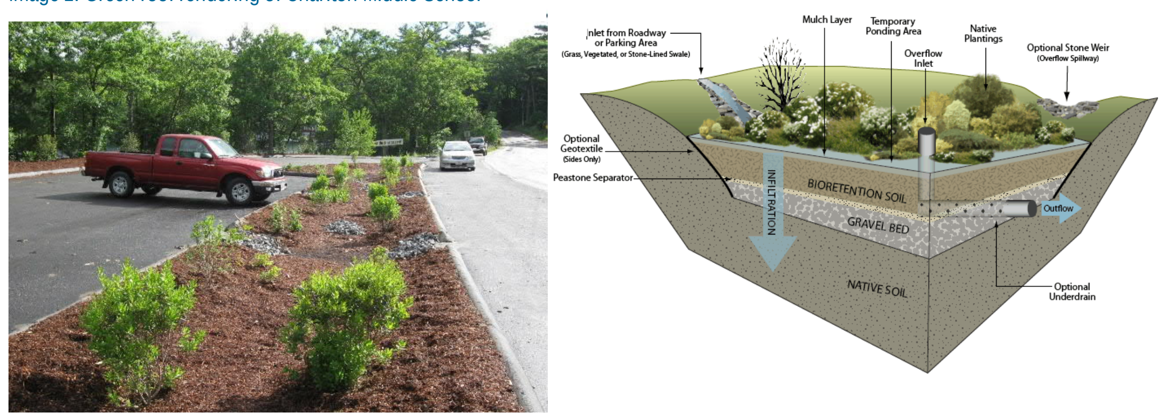
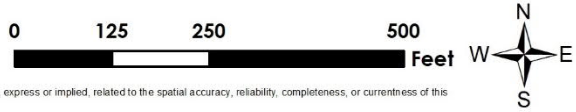


Image 3: Example of a parking lot with bioretention and diagram of a bioretention basin. Image source: MA Clean Water Toolkit.

Charlton Middle School, Charlton, MA

Site Number: 2 May 2019



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Site 3 – Charlton Elementary School
Bioretention, Infiltration, and Native Plantings
Burlingame Road, Charlton, Massachusetts

Site Description

The proposed retrofit concept is located at the Charlton Elementary School on Burlingame Road. Much of the site's runoff is currently collected by catch basins and drained down the hill to the southwest. Runoff currently causes wet conditions in the playground at the rear of the school building and erosion along the stairs from the access road to an adjacent field. This field was once used as a septic system and is therefore expected to have high infiltration rates. Runoff at the front of the building currently drains into municipal storm sewers along Burlingame Road via catch basins.

Proposed Concept

- Install a bioretention basin in the island between the front parking lot and Burlingame Road to capture runoff before it enters the municipal storm sewer system.
- Install educational signage to inform students and visitors about the function and benefits of green stormwater infrastructure and low impact development.
- Install a drain along the south edge rear access road between the road and the playground fence to divert runoff away from the playground and stairs, where it is causing wet playground conditions. Install an underground infiltration system beneath the field to infiltrate the diverted water. Perform infiltration testing before committing funds to this practice, to confirm adequate infiltration rates.
- Plant native plantings, including wildflowers, ground cover, and/or shrubs at strategic locations to stabilize soils and limit erosion while providing an aesthetic benefit.
- Incorporate stormwater concepts into the school's curriculum, using the proposed retrofits as real-world examples and sites for hands-on learning.

Image 1: Location of proposed native plantings.

Bioretention Concept Summary

Total Impervious Area: 0.2 acres

Treated Water Quality Volume: 560 ft^3

Estimated Cost

Bioretention Area: $20,000

Drain and Infiltration Practice: $26,000

Native Plantings: $3,000

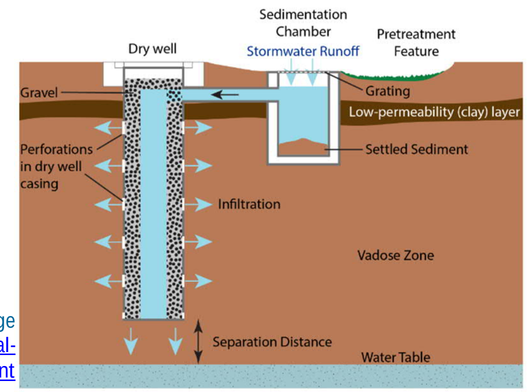


Image 2: Conceptual diagram of a dry well. Image source: https://www.americangeosciences.org/critical-issues/factsheet/dry-wells-stormwater-management

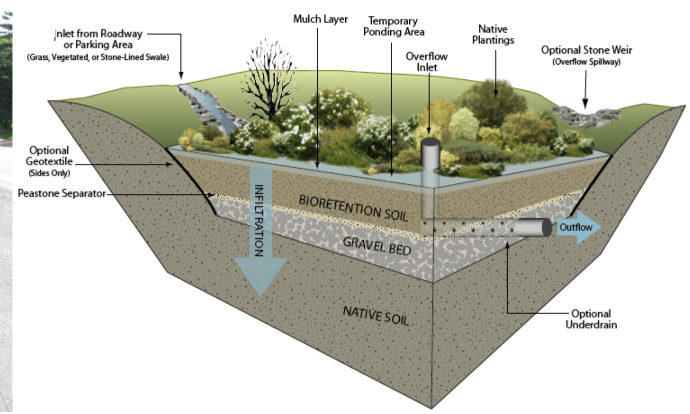
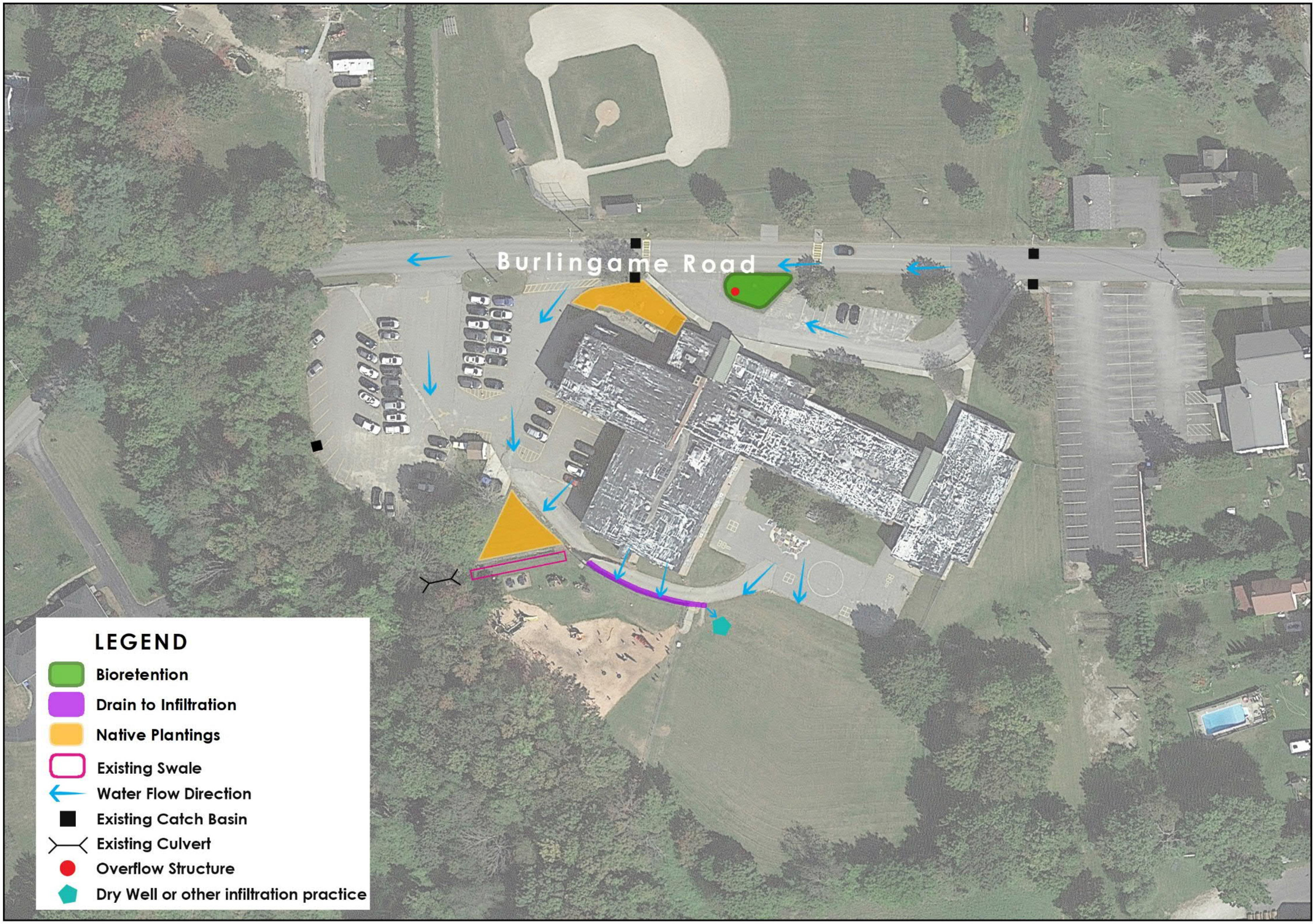


Image 3: Example of a parking lot with bioretention and diagram of a bioretention basin. Image source: MA



Charlton Elementary School, Charlton, MA

Site Number: 3 May 2019

0 25 50 100 Feet

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Site 4 – Prindle Lake Park
Bioretention
Prindle Hill Road, Charlton, Massachusetts

Site Description

The proposed retrofit is located at the existing parking lot at Prindle Lake Park, along the north shore of Prindle Lake in Charlton. The site consists of a paved asphalt parking lot with no drainage system. Runoff from the site flows down a steep slope into Prindle Lake. A guardrail separates the lot from the slope below. Prindle Hill Road contributes runoff to the site.

Proposed Concept

- Install a bioretention basin along the southwestern edge of the parking lot to capture stormwater before it flows down the steep slope toward Prindle Lake. Construct the southwestern embankment of the bioretention basin as a level spreader to evenly distribute rather than concentrate overflows.
- Include a sediment forebay or similar pretreatment structures like the one shown in Image 3 to improve treatment and extend the lifespan of the bioretention basin.
- Install educational signage to inform visitors about the function and benefits of green stormwater infrastructure and low impact development.

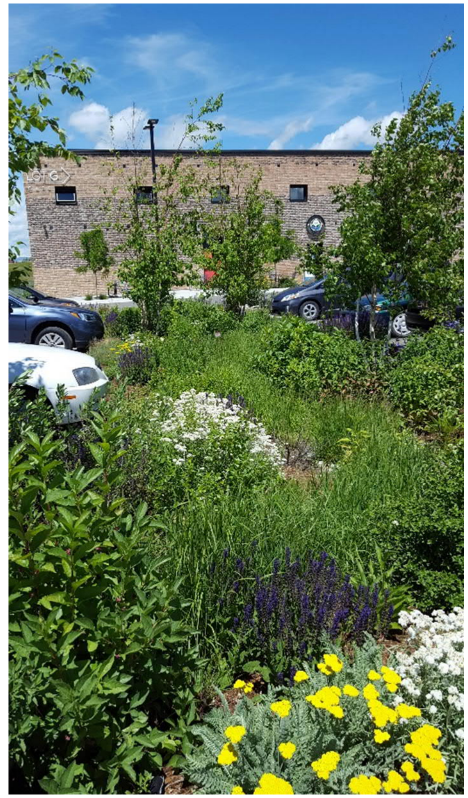

Image 2: Example of an established bioretention basin.

Bioretention Concept Summary
Total Impervious Area: 0.4 acres
Treated Water Quality Volume: 1,600 ft^3

Estimated Cost
Bioretention: $28,000

Image 3: View of current parking lot and proposed bioretention area.

Image 1: Example of a parking lot with bioretention and diagram of a bioretention basin. Image source: MA Clean Water Toolkit.

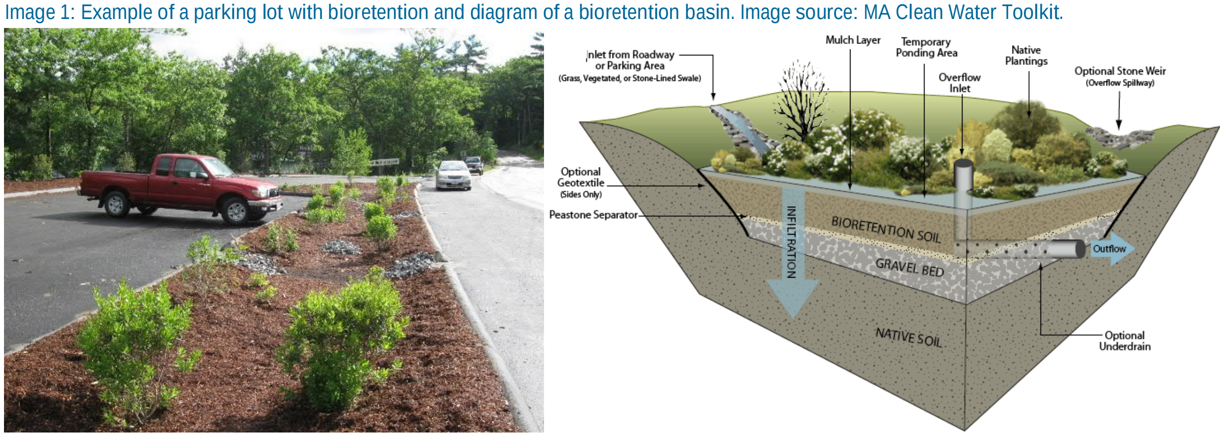

Image 4: Example of an established bioretention basin with a concrete curb cut and concrete pretreatment structure to remove sediment before runoff enters the planted portion of the basin.

Prindle Lake Park, Charlton, MA

Site Number: 4 May 2019

0 25 50 100 Feet

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Site 5 – Maynard Farm Recreation Area Bioretention

Route 31/Dresser Hill Road, Charlton, Massachusetts

Site Description

The proposed retrofit is located at the largest and most heavily used parking lot at the Maynard Farm Recreation Area. Three parking lots serve the facility. The largest parking lot (the first lot when entering the site from Dresser Hill Road) is paved but the asphalt is in poor condition and the parking lot requires repaving. Runoff from the lot drains to an existing armored swale along the southern edge of the lot. The runoff concentrates at several locations before entering the swale, which has led to rilling and erosion at the edge of the lot. The swale discharges to a wetland/pond south of and downslope from the swale via an eroded ravine that has been armored with stone. Existing storm sewers along Route 31 do not capture runoff from the parking lots.

Proposed Concept

- Retrofit the existing swale to create a series of bioretention basins connected by the swale. Move the southern edge of the lot approximately 5-10 feet as needed to provide room for the bioretention basins. Install a curb along the southern edge of the lot with curb cuts to allow water to enter the bioretention basin at discrete sites (especially if the basin is constructed before the lot is repaved). Include sediment forebays or similar pretreatment structures at each curb cut, as shown in Image 4, to improve treatment and extend the lifespan of the bioretention basin.
- Install overflow drains to convey high flows to the municipal storm sewer beneath Route 31, or construct the southern edge of the basin as a level spreader to disperse rather than concentrate overflows into the forest along the southern edge of the lot.
- If possible, repave the lot concurrently with bioretention basin installation, but prevent runoff from the lot from entering the bioretention basin until the lot is completely stabilized. Runoff should be handled using an alternate method until the site is stabilized to prevent sediment from clogging the basin.
- Adjust snowplowing practices to prevent plowing of snow into the bioretention basin during winter months. Plowing snow into the bioretention basin would cause it to fail. Snow should be plowed toward the north, west, or east sides of the lot.
- Install educational signage to inform visitors about the function and benefits of green stormwater infrastructure and low impact development.

Image 1: Existing swale and runoff forming concentrated flow over the embankment into the swale.

Image 2: Severe erosion at the outlet of the existing swale.

Bioretention Concept Summary

Total Impervious Area: 1.4 acres

Treated Water Quality Volume: 4,900 ft^3

Estimated Cost

Bioretention: $44,000

Image 3: Example of an established bioretention basin with a concrete curb cut and pretreatment structure to remove sediment before runoff enters the planted portion of the basin.

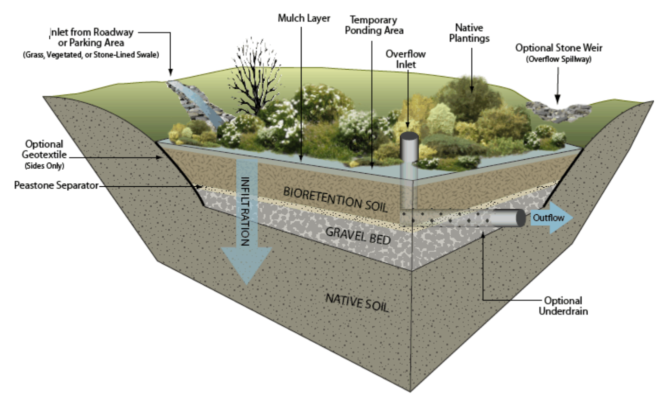

Image 4: Example of a parking lot with bioretention and diagram of a bioretention basin. Image source: MA Clean Water Toolkit.

Maynard Farm Recreation Area, Charlton, MA

Site Number: 5 May 2019

0 25 50 100 Feet

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Site 6 – Howe State Park
Bioretention and Pavement Removal
Howe Road, Spencer, Massachusetts

Site Description

The proposed retrofit site is the parking lot to the east of Howe Mill Pond in Howe State Park, which is owned by the Massachusetts Department of Conservation and Recreation (DCR). The parking lot consists of four paved asphalt parking bays connected by access driveways on the eastern and western sides of the bays. Runoff from the parking bays is collected by catch basins (1 per bay) and is discharged to the Cranberry River via an outlet located north of Howe Road. The parking lot is surrounded on three sides by tall pines, which drop needles into the parking lot. These needles and other debris have covered and clogged the catch basin inlets to the point of obscuring their location.

Proposed Concept

- Assess parking utilization during periods of peak usage and consider reducing impervious cover at the site by removing parking. Consider converting a portion of the existing excess parking spaces to an alternate use (wooded, picnic, playground) or to permeable parking (grass parking, permeable pavers, or similar permeable material suitable for low-traffic applications). In parking bays that have been completely removed, also remove catch basins and other stormwater infrastructure that is no longer needed.
- After removing unneeded parking areas, install bioretention areas to treat runoff from the remaining paved areas. Working from below the first parking bay (between the parking lot and the Howe Road) and proceeding uphill, convert one or more of the existing grass islands into bioretention basin. Direct overflow into the existing storm drainage system via overflow outlet structures or the existing catch basins.
- Plant the bioretention basins with trees, shrubs, and herbaceous vegetation that is acid tolerant, due to the heavy concentration of fallen pine needles. In addition to contributing to stormwater quality, trees will help shade and cool the lot during hot weather.
- Install educational signage to inform park visitors about the function and benefits of green stormwater infrastructure and low impact development and the benefit to the natural environment of the park.
- The proposed retrofits offer an opportunity for collaboration between the Town of Spencer and MADCR.

Image 1: View of existing grass island between first and second (northernmost) bays of parking lot.

Bioretention Concept Summary
Total Impervious Area: 0.7 acres
Treated Water Quality Volume: 2,500 ft^3

Estimated Cost
Bioretention: $44,000
Pavement Removal: $7,000

Image 2: Rendering of completed bioretention basin retrofit as it might appear once vegetation has filled in.

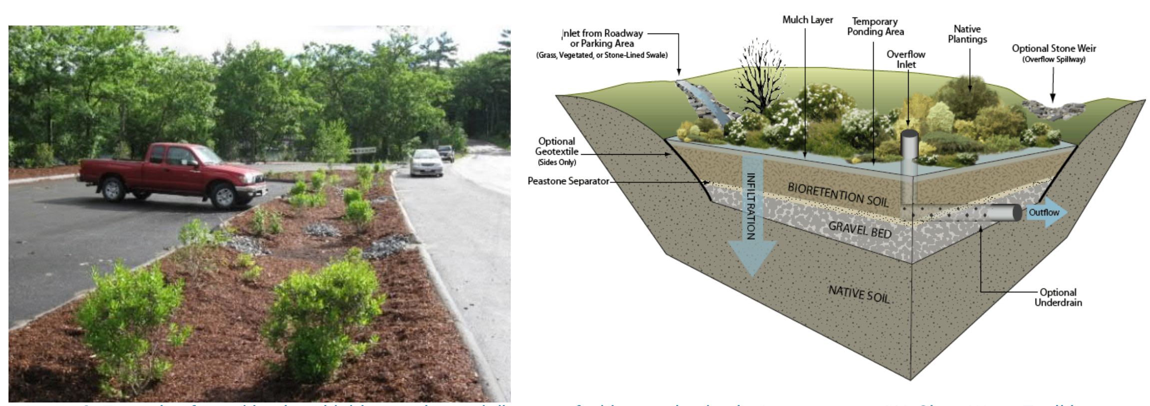

Image 3: Example of a parking lot with bioretention and diagram of a bioretention basin. Image source: MA Clean Water Toolkit.

Howe State Park, Spencer, MA

Site Number: 6 May 2019

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Bioretention, Underground Infiltration, and Permeable Pavers

Mechanic Street, Spencer, Massachusetts

Site Description

The proposed redevelopment site is located at 14, 18, and 20 Mechanic Street in downtown Spencer, MA. An existing municipal parking lot occupies 14 Mechanic Street, while the structures at 18 and 20 Mechanic Street have been demolished in preparation for redevelopment of all three lots into a single municipal parking lot. Runoff currently drains toward Mechanic Street where it enters the storm drainage system via catch basins.

Proposed Concept

- Design the parking lot with integrated bioretention basins to capture and filter parking lot runoff. Select vegetation to shade and cool the parking area while creating an aesthetically pleasing site.
- Install an underground infiltration system to allow treated rainwater to infiltrate beneath the parking lot.
- Incorporate permeable pavers into pedestrian walkways.
- Install educational signage to inform visitors about the function and benefits of green stormwater infrastructure and low impact development.

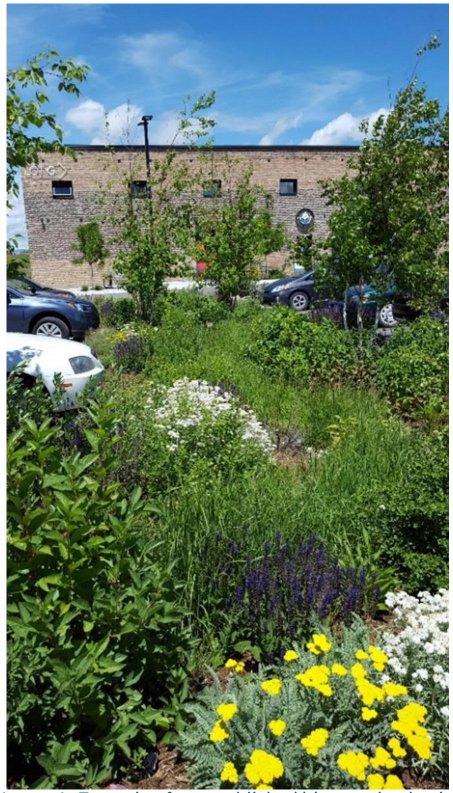

Image 1: Example of an established bioretention basin.

Concept Summary

Total Impervious Area: 0.7 acres

Treated Water Quality Volume: 2,500 ft^3

Estimated Cost

Parking Lot Redevelopment with Bioretention, Underground Infiltration, and Permeable Pavers: $495,000

Image 3: Typical installation of underground infiltration system below an existing parking lot. Image source: stormtech.com

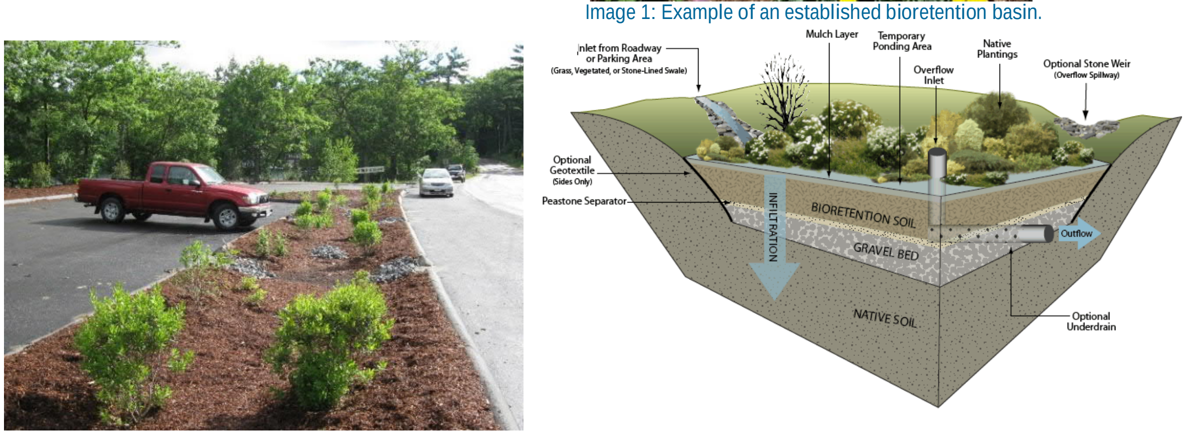

Image 2: Example of a parking lot with bioretention and diagram of a bioretention basin. Image source: MA Clean Water Toolkit.

Image 4: Typical installation of permeable paver walkway in a municipal parking lot. Image Source: Fuss & O'Neill.

Mechanic Street, Spencer, MA

Site Number: 7 May 2019

0 50 100 200 Feet

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Bioretention, Pedestrian Access Improvements, Native Plantings, and Pavement Removal

Route 9/Main Street, Spencer, Massachusetts

Site Description

The proposed retrofit concept is located at the rear of the Town Hall in Spencer, MA. The existing site consists of an upper and a lower parking lot separated by an unutilized area with no pedestrian access between the two parking lots, which are separated by a height of approximately 6-8 feet. As a result, the smaller lower parking lot is often overcrowded while the larger upper parking lot is often underutilized. Runoff from the site flows down the hill toward the commercial parking lot off Main Street, or toward the back of the upper parking lot. The site also receives runoff from upgradient properties, including the church parking lot adjacent to the upper lot. The back portion of the upper lot is used for snow storage during the winter months.

Proposed Concept

- Install an ADA accessible pedestrian ramp and/or stairway with integrated, terraced bioretention to allow pedestrian access between the upper and lower parking lots. Solicit input from Town Hall staff and the public to select a ramp and/or stairway design that meets the needs of its intended users. Note that the cost of implementation will vary depending on the design selected.
- Supplement the bioretention areas with native plantings in areas that cannot be used for bioretention (e.g., due to proximity to the foundation of the Town Hall).
- Assess parking utilization of the upper lot during periods of peak usage and consider reducing impervious cover at the site by removing parking. Consider converting a portion of the upper parking lot to an alternate use or to pervious parking (grass parking, permeable pavers, or similar permeable material suitable for low-traffic applications).
- Install educational signage to inform visitors about the function and benefits of green stormwater infrastructure and low impact development.

Image 1: Area of proposed pavement removal.

Bioretention Concept Summary

Total Impervious Area: 0.4 acres

Treated Water Quality Volume: 2,500 ft^3

Estimated Cost

Bioretention Area and Pedestrian Access Improvements (assuming installation of pedestrian ramp): $385,000

Bioretention Swale: $34,000

Pavement Removal: $20,000

Native Plantings: $2,000

Image 2: Rendering of proposed ADA accessible pedestrian ramp with integral bioretention between the upper and lower parking lots.

Spencer Town Hall, Spencer, MA

Site Number: 8 May 2019

0 25 50 100 Feet

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Site 9 – Richard Sugden Library
Bioretention and Permeable Pavers
Route 31/Pleasant Street, Spencer, Massachusetts

Site Description

The proposed retrofit concept is located at the Richard Sugden Library on Pleasant Street in downtown Spencer, MA. The site includes the library building, the lawn and sidewalk at the front of the building, and a parking area at the rear of the building with access drives on both the north and south side of the library. Runoff from the site generally drains to the southeast corner of the lot. Front and rear entry doors provide access to the library building. At the eastern edge of the parking lot, stairs climb the slope to the Price Chopper parking lot, providing access to the library for patrons of stores in the shopping plaza.

Proposed Concept

- Install bioretention basins in the lawn area in front of the main entrance of the library. Sawcut the sidewalk leading to the front entry and install a drain allowing overflows from the north basin to flow into the south basin beneath the sidewalk. Install a decorative grate over the drain to allow library patrons to see the flow of water beneath the great and to facilitate maintenance of the drain.
- Install permeable pavers to form a crosswalk from the base of the stairs at the edge of the parking lot to the top of the ramp leading to the rear door of the library. If feasible, continue the installation of the permeable pavers down the ramp to the library door. Design the pavers with a color scheme and shape that helps convey their role in stormwater treatment and infiltration. The pavers would reduce stormwater runoff and may increase pedestrian safety in the parking lot.
- Install educational signage to inform visitors about the function and benefits of green stormwater infrastructure and low impact development. Programs could also be developed at the library integrating stormwater practices as real-world and hands-on learning opportunities.

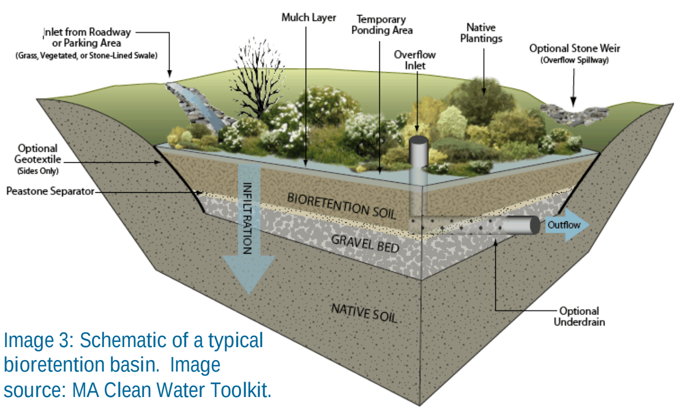

Image 3: Schematic of a typical bioretention basin. Image source: MA Clean Water Toolkit.

Image 1: View of existing ramp with proposed area of permeable pavers.

Bioretention Concept Summary

Total Impervious Area: 0.1 acres

Treated Water Quality Volume: 190 ft^3

Estimated Cost

Bioretention: $10,000

Permeable Pavers: $10,000

Image 2: Rendering of proposed bioretention basins.

Image 4: Typical installation of a permeable paver walkway in a municipal parking lot. Image Source: Fuss & O'Neill.

Richard Sugden Library, Spencer, MA

Site Number: 9 May 2019

0 25 50 100 Feet

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Site 10 – O'Gara Park
Wetland Buffer Restoration and Native Plantings
Valley Street, Spencer, Massachusetts

Site Description

The proposed retrofit concept is located at O'Gara Park at the south end of Valley Street in Spencer, MA. The site consists of an athletic field and a partially paved parking and snow storage area separated from the athletic field by a chain link fence and a steep slope. The snow storage area is unpaved and is directly adjacent to a large wetland complex located to the west. A berm of soil, mulch, and other materials has built up along the edge of the lot between the wetland and the lot by the plowing of snow toward the edge of the lot. At the north end of the lot, runoff discharges directly to a stream on the east side of Valley Street that then flows west under Valley Street and enters the wetland complex to the west.

Proposed Concept

- Plant trees and other salt-tolerant riparian vegetation in an approximatley 40-foot-wide strip along the western edge of the parking lot to help filter runoff from the parking lot before it enters the wetland, particularly melting snow during the winter and spring. If space is available and additional treatment is desired, expand the width of the buffer.
- Install native plantings along the slope between the athletic field and the parking lot to help stabilize the soil and provide aesthetic and ecological benefits.
- Consider regrading the northern end of the parking lot to redirect runoff (that currently discharges directly to the stream) to the restored vegetated buffer for enhanced filtration, pollutant removal, and flow attenuation.

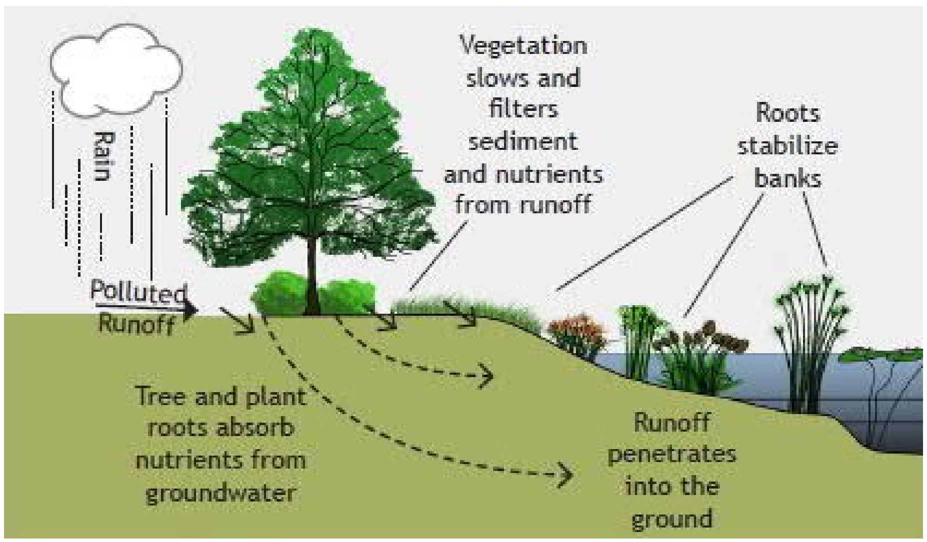

Image 1: Conceptual Diagram of a Riparian Buffer. Image source: https://www.catawbariverkeeper.org/2017/04/25/nc-senate-passes-bill-eliminates-catawba-river-buffer-protection-prevents-local-water-quality-buffers/

Buffer Restoration Concept Summary
Buffer Area Restored: 0.5 acres

Estimated Cost
Riparian Restoration: $8,000
Native Plantings: $3,000

Image 2: Berm of plowed material at the edge of the parking lot.

Image 3: Stream at the north end of the project site.

O'Gara Park, Spencer, MA

Site Number: 10 May 2019

0 75 150 300 Feet

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Policy and Regulatory Recommendations

1. ***Review and update existing municipal land use policy and regulations to require and eliminate barriers to the use of green infrastructure and LID for new development and redevelopment projects and to meet MS4 Permit requirements.***

Flood resiliency can be enhanced through well-informed land use policy and municipal land use regulations by preserving undeveloped land, siting development in locations less vulnerable to flooding, and promoting designs that reduce runoff and are less likely to be damaged in a flood. Municipal land use policies and regulations also play an important role in protecting water quality and natural resources.

The Town of Spencer has adopted requirements for green infrastructure or LID in their local Stormwater Bylaw and Regulations, which reference the LID standards and design guidance contained in the latest edition of the *Massachusetts Department of Environmental Protection Stormwater Management Handbook* (*Massachusetts Stormwater Handbook*). Similarly, the Town of Charlton implements stormwater management requirements for new development and redevelopment projects through a local Stormwater Bylaw administered by the Charlton Conservation Commission. The Charlton Stormwater Bylaw references the specifications and standards of the *Massachusetts Stormwater Management Policy*, which is now incorporated in the *Massachusetts Stormwater Handbook* and includes information on the use of LID.

EPA's current Massachusetts Municipal Separate Storm Sewer System General Permit (MS4 Permit) requires regulated municipalities, including Charlton and Spencer, to update their local land use bylaws and/or regulations for consistency with the post-construction stormwater management standards contained in the permit. The permit also requires both communities to review their land use regulations to eliminate any barriers or impediments to the use of green infrastructure and LID such as street design and parking lot guidelines, as well as identify potential stormwater retrofit projects to reduce impervious area and stormwater pollutant loads.

Charlton and Spencer, working through the Central Massachusetts Regional Stormwater Coalition (CMRSWC), should review and update their local land use policies and regulations/bylaws to promote the use of green infrastructure and LID and to meet MS4 Permit requirements.

2. ***Update design storm precipitation amounts in state and local land use regulations and policies to promote more resilient stormwater drainage design.***

As discussed in the Road-Stream Crossings recommendations, stormwater and drainage-related infrastructure should be designed with storm intensities based on NOAA Atlas 14 (or NRCC atlas) to represent current precipitation conditions. For more resilient water infrastructure design, including improved stream crossings, consider designing for a 20% increase in design rainfall intensity, which is consistent with climate change projections for extreme precipitation under a medium to high emissions scenario and a 50- to 100-year planning horizon. The towns should revisit these recommendations relative to the revised design storm intensities that are expected to be issued as part of the updated *Massachusetts Stormwater Handbook* and state wetland regulations.

3. ***Pursue sustainable, long-term funding sources for large-scale GI implementation.***

A stormwater utility operates much like a drinking water or sewer utility. Fees collected from property owners go into a dedicated fund to pay for the operation and maintenance of stormwater infrastructure. Stormwater utilities, which create a more equitable relationship between revenues collected and runoff generated from a site, are common in many parts of the U.S., although relativly few have been implemented in New England. Massachusetts communities with stormwater utilities include but are not limited to Ashland, Braintree, Milton, Northampton, Newton, Reading, Shrewsbury, and Westfield. Other smaller communities in western and central Massachusetts, such as Belchertown and Agawam, are also in the process of implementing stormwater utilities.

Stormwater utilities could provide a dedicated source of funding to construct and maintain green stormwater infrastructure, implement drainage system improvements (including culvert upgrades or replacements), and address MS4 permit compliance.

A list of additional funding sources, including grant and loan programs, is maintained by the Commonwealth of Massachusetts at https://www.mass.gov/service-details/available-funding-for-stormwater-projects-in-massachusetts.

6 Funding Sources

In addition to traditional municipal funding sources (i.e., the use of General Funds and municipal bonds), a variety of state and federal sources are also available to provide financial assistance for implementation of the plan recommendations. The funding sources identified in this section should be re-evaluated periodically to account for potential changes to existing funding programs (i.e., priorities, eligibility, funding cycles, and amounts) and to identify new or emerging sources of funding for flood mitigation, climate resiliency, and habitat restoration projects.

6.1 State Funding Sources

Dam and Seawall Repair or Removal Program

The Dam and Seawall Repair or Removal Fund was established in 2013 to promote ecological restoration, public health, and public safety. Currently, there are two types grant programs and one loan program that municipalities can apply for (Commonwealth of Massachusetts, n.d.):

- A program to support the completion of designs and permit applications to repair or remove dams, levees, and seawalls and other coastal infrastructure
- A program to support the construction phase of repair or removal of dams, levees, and seawalls and other coastal infrastructure
- A loan to support the construction phase of repair or removal of dams, levees, and seawalls and other coastal infrastructure

Website: https://www.mass.gov/service-details/dam-and-seawall-repair-or-removal-program-grants-and-funds

Division of Ecological Restoration (DER) Project Grants

The DER offers small grants to fund wetland, river, and flow restoration projects that are high-priority and provide significant ecological and community benefits to the Commonwealth. The DER considers funding for several types of "priority projects," including dam removal and culvert replacements. In addition to small grants, eligible projects also receive technical services (data collection, engineering, design work, and permitting) and project management and fundraising help.

DER website: https://www.mass.gov/how-to/become-a-der-priority-project
Dam removal website: https://www.mass.gov/river-restoration-dam-removal)
Culvert replacements website: https://www.mass.gov/river-restoration-culvert-replacements

State Revolving Fund (SRF) Loan Program

The SRF provides a low-cost financing option for communities through two programs: the Clean Water Program and the Drinking Water Program. The Clean Water Program provides loans to help municipalities comply with federal and state water quality requirements by focusing on watershed management priorities, stormwater management, and green infrastructure. The Drinking Water SRF Program provides loans to communities to improve water supply infrastructure and drinking water safety.

SRF Clean Water Program website: https://www.mass.gov/service-details/srf-clean-water-program
SRF Drinking Water Program website: https://www.mass.gov/service-details/srf-drinking-water-program

Clean Water Act, Section 319 Nonpoint Source Implementation Grants

Section 319 Grants are available for projects that promote restoration and protection of water quality through reducing and managing nonpoint source pollution. These grants are made possible by federal funds provided to MassDEP by the USEPA under Section 319 of the Clean Water Act. Eligible applicants include municipal, state, or regional governments, quasi-state agencies, public schools and universities, and non-profit watershed, environmental, or conservation organizations. Pursuant to federal guidelines for Section 319 funding, projects can only be funded in those areas in which a Watershed-Based Plan has been completed. MassDEP created the Massachusetts Watershed-Based Plan (WBP) for all watersheds in the state that can be used to develop proposals for 319 grants.

Clean Water Act Section 319 grants may be used for green stormwater infrastructure projects (if not mandated by a stormwater permit) and certain restoration activities such as dam removal. The EPA's guidance, "Nonpoint Source Program and Grants Guidelines for States and Territories," includes hydrologic modification as a type of nonpoint source pollution and therefore projects that address hydrologic modification such as dam removal are potentially eligible for funding. Dam removal projects need to be consistent with a state's written Nonpoint Source Management Program Plan. Dam removal projects that are included in local watershed-based plans that are consistent with EPA Guidelines would also be eligible for 319 funds.

MassDEP WBP website: https://www.mass.gov/guides/watershed-based-plan-information
MassDEP 319 website: https://www.mass.gov/info-details/grants-financial-assistance-watersheds-water-quality

Chapter 90 Program

The Chapter 90 program is operated by the Massachusetts Department of Transportation. The program provides 100% reimbursement for approved roadway projects, including projects such as road resurfacing, roadside drainage structures, bridges, side road approaches, and landscaping and tree planting.

Website: https://www.mass.gov/chapter-90-program

MassWorks Infrastructure Program

The MassWorks Infrastructure Program is administered by the Executive Office of housing and Economic Developing, the Department of Transportation, and the Executive Office for Administration and Finance. The program provides public infrastructure funding to support sustainability in Massachusetts, as well as job creation and economic development. Although the program is not specifically for hazard mitigation, the infrastructure improvements covered under MassWorks could help protect communities from natural disasters such as flooding.

Website: https://www.mass.gov/service-details/massworks-infrastructure-grants

6.2 Federal Funding Sources

HUD Community Development Block Grants

Title 1 of the Housing and Community Development Act of 1974 authorized the Community Development Block Grant program. The program is sponsored by the US Department of Housing and Urban Development. The Massachusetts program is administered through the Massachusetts Department of Housing and Community Development.

CDBG-DR (disaster recovery) funds may be used to restore public facilities and infrastructure, rehabilitate or replace housing, acquire property, promote economic revitalization, and support hazard mitigation planning. CDBG-DR funds are intended to support long-term recovery from a specific natural disaster and may not be applied to recovery activities associated with other disasters. Annual CDBG Program funds may also be used for certain eligible hazard mitigation and disaster recovery activities (Commonwealth of Massachusetts, n.d.). Implementation of green stormwater infrastructure and drainage system upgrades to mitigate drainage-related flooding is potentially eligible for CDBG funding.

Website: https://www.mass.gov/service-details/community-development-block-grant-cdbg

Army Corps of Engineers Aquatic Ecosystem Restoration Program

Under Section 206 of the Water Resources Development Act of 1996 (33 U.S.C. 2330), the Army Corps of Engineers can participate in the study, design and implementation of ecosystem restoration projects. Projects conducted in New England under this program have included eelgrass restoration, salt marsh and salt pond restoration, freshwater wetland restoration, anadromous fish passage and dam removal, river restoration, and nesting bird island restoration. Projects must be in the public interest and cost effective and are limited to $10 million in Federal cost.

Non-Federal project sponsors must be public agencies or national non-profit organizations capable of undertaking future requirements for operation, maintenance, repair, replacement and rehabilitation (OMRR&R), or may be any non-profit organization if there are no future requirements for OMRR&R. The Corps of Engineers provides the first $100,000 of study costs. A non-Federal sponsor must contribute 50 percent of the cost of the feasibility study after the first $100,000 of expenditures, 35 percent of the cost of design and construction, and 100 percent of operation and maintenance costs.

Website: http://www.nae.usace.army.mil/Missions/Public-Services/Continuing-Authorities-Program/Section-206/

NFWF New England Forests and Rivers Fund

The National Fish and Wildlife Foundation (NFWF) New England Forests and Rivers Fund is dedicated to restoring and sustaining healthy forests and rivers that provide habitat for diverse native bird and freshwater fish populations in the six New England states. This program annually awards competitive grants ranging from $50,000 to $200,000 each. Since its creation in 2015, the Fund has awarded 48 grants to restore early successional habitat, modify and replace barriers to fish movement, restore riparian and instream habitat, and engage volunteers in forest habitat restoration and stream connectivity projects. Major funding for the New England Forests and Rivers Fund is provided by Eversource Energy, the U.S. Fish and Wildlife Service, and the U.S. Department of Agriculture's Natural Resources Conservation Service and Forest Service.

Website: http://www.nfwf.org/newengland/Pages/home.aspx

USDA NRCS Funding Programs

The USDA Natural Resources Conservation Service (NRCS) works with land owners in Massachusetts to improve and protect soil, water, and other natural resources. NRCS has several funding programs in Massachusetts that help property owners address flooding and water quality issues.

- **The Emergency Watershed Protection (EWP) Program** is designed to help people and conserve natural resources by relieving imminent hazards to life and property caused by floods, fires, wind-storms, and other natural occurrences. EWP is an emergency recovery program, which responds to emergencies created by natural disasters. It is not necessary for a national emergency to be declared for an area to be eligible for assistance. EWP is designed for installation of recovery measures. Activities include providing financial and technical assistance to remove debris from stream channels, road culverts, and bridges, reshape and protect eroded banks, correct damaged drainage facilities, establish cover on critically eroding lands, repair levees and structures, and repair conservation practices.

  Website: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/ewpp/

- **The Emergency Watershed Protection - Floodplain Easement Program (EWP-FPE)** provides an alternative measure to traditional EWP recovery, where it is determined that acquiring an easement in lieu of recovery measures is the more economical and prudent approach to reducing a threat to life or property. The easement area is restored to the maximum extent practicable to its natural condition using structural and nonstructural practices to restore the flood storage and flow, erosion control, and improve the practical management of the easement. Floodplain easements restore, protect, maintain and enhance the functions of floodplains while conserving their natural values such as fish and wildlife habitat, water quality, flood water retention and ground water recharge. Structures, including buildings, within the floodplain easement must be demolished and removed, or relocated outside the 100-year floodplain or dam breach inundation area.

  Website:
  https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ct/programs/financial/ewp/?cid=stelprdb1244478

- **The Watershed and Flood Prevention Operations Program** provides technical and financial assistance to states, local governments and Tribes to plan and implement watershed project plans for the purpose of watershed protection, flood mitigation, water quality improvement, fish and wildlife enhancement, wetlands and wetland function creation and restoration, groundwater recharge, and wetland and floodplain conservation easements.

  Website: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/wfpo/

FEMA Hazard Mitigation Assistance Grant Programs

The Federal Emergency Management Agency (FEMA) administers two major programs related to hazard mitigation: the National Flood Insurance Program (see Section 3.1 of this plan) and the Hazard Mitigation Assistance Program. FEMA's hazard mitigation assistance grant programs provide funding to protect life and property from future natural disasters. In Massachusetts, these programs are administered by the Massachusetts Emergency Management Agency (MEMA). FEMA flood hazard mitigation assistance funding is available to Massachusetts communities through the following programs:

- **Building Resilient Infrastructure and Communities (BRIC)** BRIC provides funds to support public infrastructure projects that increase a community's resiliency to reduce to effects of future disasters. The goal of the program is to reduce overall risk to the population and structures, while at the same time, also reducing reliance on Federal funding from actual disaster declarations. The program was introduced in October 2018 and as of June 2019 is still under a public comment period. The BRIC program is replacing the Pre-Disaster Mitigation (PDM) program.

- **Flood Mitigation Assistance (FMA)** provides funds for projects to reduce or eliminate risk of flood damage to buildings that are insured under the National Flood Insurance Program (NFIP) on an annual basis. These are cost share grants for pre-disaster planning and projects, with a federal share (up to 100%) and non-federal share (local government or other organization).

- **Severe Repetitive Loss (SRL)** is designed to reduce flood damages to residential properties that have experienced SRLs under flood insurance coverage. The program provides funds that measures can be taken to reduce or eliminate risk of flood damage to buildings insured under the NFIP. Funding is available on an annual basis (as available). SRL provides up to 90% Federal funding for eligible projects.

- **Hazard Mitigation Grant Program (HMGP)** assists in implementing long-term hazard mitigation measures following Presidential disaster declarations. Funding is available to implement plans or projects in accordance with State, Tribal, and local priorities. HMGP grants are post-disaster cost share grants consisting of 75% federal share and 25% non-federal share (local government or other organization).

- **Public Assistance (PA) Grants** provide assistance to local, tribal and state governments and certain types of Private Non-Profit (PNP) organizations so that communities can quickly respond to and recover from major disasters or emergencies declared by the President. Through the PA Program, supplemental Federal disaster grant assistance is provided for debris removal, emergency protective measures, and the repair, replacement, or restoration of disaster-damaged, publicly owned facilities and the facilities of certain PNP organizations. The PA Program also encourages protection of these damaged facilities from future events by providing assistance for hazard mitigation measures during the recovery process.

Website: https://www.fema.gov/hazard-mitigation-assistance

Community Rating System (CRS) under NFIP

The Community Rating System is a voluntary program under the NFIP that encourages municipalities to participate in flood management actives that exceed the minimum requirements of the NFIP. There are three goals of the CRS: reduce flood damage to insurable property, strengthen and support the insurance aspects of the NFIP, and encourage a comprehensive approach to floodplain management. Communities participating in the CRS receive reduced insurance premiums as a result of their compliance.

Website: https://www.fema.gov/community-rating-system

Repetitive Flood Claims (RFC) under NFIP

The RFC grant program provides funding on an annual basis to reduce or eliminate long-term risk flood damages to properties covered by the NFIP that have had one or more claim payments for flood damages. RFC provides up to 10% of federal funds. RFC only applies to properties in NFIP-insured communities that do not meet requirements of the Flood Mitigation Assistance program (FMA) because they do not have the capacity to manage the activities or cannot provide the non-federal cost share.

Website: https://www.fema.gov/repetitive-flood-claims-grant-program-fact-sheet

6.3 Other Funding Sources

Healthy Watersheds Consortium Grant Program - U.S. Endowment for Forestry and Communities, USEPA, USDA NRCS

The goal of the Healthy Watersheds Consortium Grant Program is to accelerate strategic protection of healthy, freshwater ecosystems and their watersheds. The program supports:

- Developing funding mechanisms, plans, or other strategies to implement large-scale watershed protection, source water protection, green infrastructure, or related landscape conservation objectives.
- Building the sustainable organizational infrastructure, social support, and long-term funding commitments necessary to implement large-scale protection of healthy watersheds.
- Supporting innovative or catalytic projects that may accelerate funding for or implementation of watershed protection efforts, or broadly advance this field of practice.

Eligible applicants include not-profit organizations, for-profit companies, tribes, intertribal consortia, interstates, state, and local government agencies including water utilities and wastewater facilities, and colleges and universities. Funding amounts range from $50,000 to $300,000.

Website: https://www.epa.gov/hwp/healthy-watersheds-consortium-grants-hwcg

Resilient Communities Program

Wells Fargo, in partnership with the National Fish and Wildlife Foundation, launched the Resilient Communities Program in 2017. The program is designed to prepare for future environmental challenges by enhancing community capacity to plan and implement resiliency projects and improve the protections afforded by natural ecosystems by investing in green infrastructure and other measures. The program will focus on water quality and quantity declines, forest health concerns, and sea level rise. The program emphasizes community inclusion and assistance to traditionally underserved populations in vulnerable areas. In the northeast, eligible project types include wetland restoration and aquatic organism passage. The program will awarded approximately $2 million in grants to projects in 2019. Each grant will range from $100,000 to $500,000 depending on category and will be awarded to eligible entities working to help communities become more resilient. This program has one round of applications per year and awards approximately 3 to 6 grants annually.

Website: http://www.nfwf.org/resilientcommunities/Pages/home.aspx

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Appendix A

Flooding Vulnerability Tables

FUSS & O'NEILL

Table 1. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Charlton

Vulnerability Point	Flooding Source	Description	Information Source
Sewer System		Infiltration and inflow suspected. Assess for upgrades to prevent CSOs during heavy precipitation.	MVP CRB Workshop
Sewer pump stations (12)		Back-up power supply; assess vulnerability; perform improvements.	MVP CRB Workshop
Public water supply line entering Charlton from Southbridge		Currently the sole public water supply. Buffumville – create redundant water supply for all hazards.	MVP CRB Workshop
Public Safety Complex		Located in a low-lying area which makes it vulnerable to flooding.	MVP CRB Workshop
Uncapped Landfill		Flint Road	MVP CRB Workshop
Stafford Street Culvert	Little Nugget Lake	Outflow from Little Nugget Lake causes flooding; assess vulnerability to make improvements; replace. Culvert submerged in 0.2% Annual Chance Flood1% Annual Chance Flood within 0.5 foot of top of culvert entrance.	MVP CRB Workshop *FEMA FIS
Brookfield Road Bridge		Partial blockage restricts flow under bridge.	MVP CRB Workshop
Beaver Dam at Dresser Hill Road		Issue is near the intersection of Dresser Hill Road (Route 31) and Baylies Road.	MVP CRB Workshop
Beaver Dams at Guelphwood Road	Unnamed pond and wetland complex	Dam Failure	MVP CRB Workshop
Beaver Dam at North Sturbridge Road	Pratt Brook	Flooding and Dam Failure (Beaver Dam).	MVP CRB Workshop
Dam (McIntyre Pond)	Headwaters of Deans Brook	Dam overtops for 10% to 0.2% Annual Chance Floods.	FEMA FIS
Culvert @ Sandersdale Road near Peale Drive	Deans Brook	Road overtops for 2% to 0.2% Annual Chance Flood.	FEMA FIS
US Route 20 Bridge	Cady Brook	Road overtops for 0.2% Annual Chance Flood. Water surface elevation at or just below low chord of bridge for 1% Annual Chance Flood.	FEMA FIS
State Route 169 (North of Carpenter Hill Road) Bridge	Cady Brook	Water surface elevation at top of road for 0.2% Annual Chance Flood.	FEMA FIS
State Route 169 (North of Sherwood Lane) Bridge	Cady Brook	Road overtops for 0.2% Annual Chance Flood, Water surface elevation at or near low chord of bridge for 1% Annual Chance Flood.	FEMA FIS

Table 1. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Charlton

Vulnerability Point	Flooding Source	Description	Information Source
Grove Road Bridge	Little River	Road overtops for 0.2% Annual Chance Flood.	FEMA FIS
Oxbow Road Bridge	Little River	Road overtops for 0.2% Annual Chance Flood. 1% Annual Chance Flood at road surface. 2% Annual Chance Flood at low chord of bridge.	FEMA FIS
Turner Road Bridge	Little River	Road overtops for 0.2% Annual Chance Flood. 1% Annual Chance Flood is at road surface. 2% Annual Chance Flood is at low chord of bridge.	FEMA FIS
Culvert at I-90 (Mass Turnpike), upstream of Pikes Pond	Little Nugget Brook	Upstream end of culvert submerged for 0.2% Annual Chance Flood.	FEMA FIS
Brook Drive Culvert	Little Nugget Brook	Culvert submerged for 10% to 0.2% Annual Chance Floods.	FEMA FIS
Dam @ Little Nugget Lake	Little Nugget Brook	Dam overtops for 10% to 0.2% Annual Chance Floods.	FEMA FIS
Culvert @ Little Nugget Road, upstream of Little Nugget Lake	Little Nugget Brook	Road overtops for 10% to 0.2% Annual Chance Floods.	FEMA FIS
Mass Turnpike/I-90 Culvert	Pikes Pond Tributary	Upstream end of culvert submerged for 0.2% Annual Chance Flood.	FEMA FIS
Dodge Road Culvert	Pikes Pond Tributary	Road overtops for 10% to 0.2% Annual Chance Floods.	FEMA FIS
Stafford Street Culvert	Pikes Pond Tributary	Road overtops for 0.2% Annual Chance Flood.1% Annual Chance Flood and 2% Annual Chance Flood at top of road. Culvert entrance nearly submerged for 10% Annual Chance Flood.	FEMA FIS
Railroad (Conrail) Culvert	Pikes Pond Tributary	Culvert submerged for 0.2% Annual Chance Flood. Culvert entrance nearly submerged for 1% Annual Chance Flood.	FEMA FIS
Muggett Hill Road	Wabash Pond and Quinebaug River Tributary	500 Year Flood Area @ intersection with Freeman Road.	Charlton Local Hazard Inventory *FEMA FIS
Glen Echo Dam	Cady Brook Headwaters	In the Town of Charlton, more than 20 inches of rain fell from August 11 to August 15, 1955, over the headwaters of Cady Brook. Heavy damage to residential and commercial property occurred along the entire length of the stream. The failure of Glen Echo Dam produced a tremendous surge along Cady Brook that destroyed several other smaller dams in Charlton and continued unabated to the Quinebaug River.	FEMA FIS

Table 1. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Charlton

Vulnerability Point	Flooding Source	Description	Information Source
Dresser Hill Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Haggerty Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Burlingame Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Center Depot Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Brookfield Road	Beaver Dam	Dam Failure. Flooding.	Charlton Local Hazard Inventory
Baylies Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Bond Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Guelphwood Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Gould Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
City Depot Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Stafford Street	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Wilson Lane	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
North Sullivan Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Lower Sibley Pond Dam	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
South Sturbridge Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory

Table 1. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Charlton

Vulnerability Point	Flooding Source	Description	Information Source
Ten School House Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Southbridge Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Harrington Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Mcintyre Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
East Baylies Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Blood Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Sandersdale Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Piehl Drive	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Granite Reservoir Dam	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Potter Village Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Colburn Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Burns Lane	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Oxford Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Turner Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Richardson Corner Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory

Table 1. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Charlton

Vulnerability Point	Flooding Source	Description	Information Source
Small Farm Pond Dam	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Mayberry Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
North Sturbridge Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Brookfield Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Fire Station HQ	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
Sewer Department	Possible Flood Area	Four Locations of Critical Infrastructure in Hazard Areas	Charlton Local Hazard Inventory
Water Tank	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
Charlton Arts & Activities Center	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
Town Hall	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
Public Library	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
Water Tank – J Hammond Road	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
Tennessee Gas Pipeline	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
SBA Structures LLC Cell Site	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
Radio Tower	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
Charlton Federated Church	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory

Table 1. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Charlton

Vulnerability Point	Flooding Source	Description	Information Source
Former Charlton Woolen Mill	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
Brookfield Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Guelphwood Road	Possible Flood Area	Dam Failure	Charlton Local Hazard Inventory
Center Depot Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Burlingame Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Baylies Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Dresser Hill Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Haggerty Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Bond Road	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
Bond Road (2)	Beaver Dam	Dam Failure	Charlton Local Hazard Inventory
North Sturbridge Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Ten School House Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Southbridge Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Harrington Road Culvert	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Mcintyre Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory

Table 1. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Charlton

Vulnerability Point	Flooding Source	Description	Information Source
East Baylies Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Blood Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Blood Road (2)	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Sandersdale Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Piehl Drive	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Granite Reservoir Dam	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Brookfield Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Potter Village Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Colburn Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Burns Lane	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Oxford Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Turner Road (2)	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Turner Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Richardson Corner Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Small Farm Pond Dam	Possible Flood Area	Flooding	Charlton Local Hazard Inventory

Table 1. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Charlton

Vulnerability Point	Flooding Source	Description	Information Source
Mayberry Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Gould Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
City Depot Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Stafford St	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Wilson Lane	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
North Sullivan Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
Lower Sibley Pond Dam	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
South Sturbridge Road	Possible Flood Area	Flooding	Charlton Local Hazard Inventory
MA-31/North Main St: US-20 to Dudley Town Line	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
MA-169: US-20 to Southbridge Town Line	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
US-20: Sturbridge Town Line to Oxford Town Line	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
MA-31/Depot Road: Spencer Town Line to US-20	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
Stafford Street: Oxford Town Line to US-20	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory
Oxford Road/Muggett Hill Road: Oxford Town Line to MA-31	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory

Table 1. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Charlton

Vulnerability Point	Flooding Source	Description	Information Source
Brookfield Road: Sturbridge Town Line to US-20	Possible Flood Area	Critical Infrastructure In Hazard Area	Charlton Local Hazard Inventory

Notes:

1. FEMA FIS – Federal Emergency Management Agency, Flood Insurance Study, Worcester County, Massachusetts, Effective July 4, 2011, Revised July 16, 2014
2. Charlton Local Hazard Inventory – Local hazards identified by Town of Charlton as part of Central Massachusetts Regional Planning Commission (CMRPC) Hazard Mitigation Planning effort currently underway.
3. MVP CRB Workshop – Municipal Vulnerability Preparedness Program Community Resilience Building Workshop, Town of Charlton, April 6, 2018

Table 2. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Spencer

Vulnerability Point	Flooding Source	Description	Information Source
Public Water Supply	Town-wide drought risk outside water service area	Private wells, town wells, pump station, rural firefighting draw points, water treatment plant and pump stations. Water supply resiliency to protect town wellfields during longer droughts. *2016 drought led to very poor conditions for rural firefighting; dry hydrants clogged, cisterns dried, rivers too low to draw from. Residents outside water service area requested assistance during 2016 drought.	MVP CRB Workshop *Spencer Local Hazard Inventory
Waste Water Treatment Facility	Possible Flood Area	Aging infrastructure (+/-100 years old) and currently in flood zone. Suspected infiltration and inflow in sewer system. Sewer System. Assess for upgrades to prevent CSO's during heavy precipitation.	MVP CRB Workshop
Public Facilities		Highway department is in a flood zone and aquifer protection zone.	MVP CRB Workshop
North Spencer Road Bridge (Lac Marie Dam and Bridge)	Lac Marie	Bridge Replacement. Primary evacuation route.	MVP CRB Workshop
Turkey Hill Brook Bridge	Turkey Hill Brook	Dam failure in 1950's flooded Wire Village. Stone Dam abutment still visible near Turkey Hill Brook and Turkey Hill Brook Bridge.	Conversation with Paul Dell'Aquila during Dam Assessment 11/29/18
Stiles Causeway	Stiles Reservoir	*Stiles Reservoir Dam failure (in Leicester) flooded Putnam, CT along French River	MVP CRB Workshop *Spencer Local Hazard Inventory
Muzzy Meadow Culvert and Dam	Spencer Pond	Low point near Pope St. Downtown vulnerable to flooding. Culvert under Meadow Road. Muzzy Meadow Dam.	MVP CRB Workshop
Moose Hill Dam	Moose Hill Reservoir	Moose Hill Dam and Reservoir, located on Turkey Hill Creek in the Town of Leicester is used for flood control of the Sevenmile River. The release facilities for this purpose are uncontrolled. When a 1-percent-annual chance storm is routed starting from the permanent pool, the maximum water level stays well below the emergency spillway crest.	Dam identified in MVP CRB Workshop. Flood information from FEMA FIS.
Cranberry Meadow Pond Dam	Cranberry Meadow Pond.	*Cranberry River. 100 year flood zone. Dam Failure. Downstream Hazards include roads and residences.	MVP CRB Workshop *Spencer Local Hazard Inventory
Whittemore Dam	Lake Whittemore	Dam Failure	MVP CRB Workshop *Spencer Local Hazard Inventory

Table 2. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Spencer

Vulnerability Point	Flooding Source	Description	Information Source
Sugden Dam (High Priority)	Sugden Reservoir	Major Dam repairs in next 5-10 years ($.5-1million) *Dam failure	MVP CRB Workshop *Spencer Local Hazard Inventory
Browning Pond Road, Bridge, and Dam (High Priority)	Browning Pond @ Browning Pond Dam; 100 year flood zone (in)	Dam crest supports Browning Pond Road and vulnerable to overtopping. Town is planning work to address flooding below dam.	MVP CRB Workshop
State Route 9 Bridge (above confluence with Cranberry River)	Sevenmile River	Above low chord of bridge for 0.2% Annual Chance Flood. 1.5' below low chord of bridge for 1% Annual Chance Flood.	FEMA FIS
Smithville Road Bridge	Sevenmile River	Road overtops for 2% to 0.2% Annual Chance Floods. 10% Annual Chance Flood above low chord of bridge.	FEMA FIS
State Route 31	Sevenmile River	Water surface elevation at top of road for 0.2% Annual Chance Flood. 1% Annual Chance Flood above low chord of bridge. 2% Annual Chance Flood just below low chord of bridge.	FEMA FIS
Pine Acres Road	Turkey Hill Brook; 100 year flood zone (abuts)	Road and home flooding. New culvert installed but still floods; private road.	Spencer Local Hazard Inventory
55 and 40 GH Wilson Road	Watson Millpond and brook (#55); Alder Meadow (swamp) (#40); 100 year flood zone (abuts)	Near #55 and #40. Road and home flooding.	Spencer Local Hazard Inventory
Clark Road	Stiles Reservoir; 100 year flood zone (abuts)	Causeway over Stiles Res. Road flooding (underwater during high water).	Spencer Local Hazard Inventory
North Spencer Road	Tributary of Sevenmile River	Just north of Northwest Road (near Cooney Road). Road flooding. Undersized culvert.	Spencer Local Hazard Inventory
North Spencer Road (2)	Browning Pond tributary	South of Thompson Pond Road. Road and home (occasional) flooding. New culvert installed recently; culvert is still undersized; problem not fixed.	Spencer Local Hazard Inventory
190 Northwest Road	Brooks Pond tributary; wetland; 100 year flood zone (in)	At Oakham town line (near #190)	Spencer Local Hazard Inventory

Table 2. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Spencer

Vulnerability Point	Flooding Source	Description	Information Source
Cranberry Meadow Road	Cranberry River; Cranberry Meadow Pond Dam; wetlands; 100 year flood zone (in)	Road flooding	Spencer Local Hazard Inventory
Highland Street	Outflow brook below Whittemore Dam; 500 year flood zone (near)	North of Delude Ave. Home flooding (very frequent)	Spencer Local Hazard Inventory
North Spencer Road (3)	Sevenmile River; tributaries; wetlands	From Alta Crest Road to Hastings Road. New culverts installed; problem fixed.	Spencer Local Hazard Inventory
Greenville Street	Burncoat Pond tributary; wetlands; beavers; 500 year flood zone (abuts)	East of Kingsbury Road (the northern of the two intersections of Greenville and Kingsbury). Road and home flooding.	Spencer Local Hazard Inventory
127 Ash Street	Morgan Swamp tributary	Near #127. Road flooding.	Spencer Local Hazard Inventory
7 Smithville Cross Road	Tributary of Sevenmile River; stormwater runoff; 100 year flood zone (in)	Road flooding; runoff is also drained to a low grassy area near the road.	Spencer Local Hazard Inventory
Cider Millpond, Lincoln Street	Outflow brook below Whittemore Dam; wetlands; 100 year flood zone (in)	Dam failure and flooding Behind Price Chopper. Home flooding (Lincoln Street); outlet brook is underground as a result of 1955 flood; pond floods when outlet fills.	Spencer Local Hazard Inventory
50 Smithville Road	Tributary of Sevenmile River; stormwater runoff; 100 year flood zone (in)	Road flooding; runoff is also drained to a low grassy area near the road.	Spencer Local Hazard Inventory
Charlton Road	Cranberry River tributary	At Howe Road. New culverts installed recently; problem fixed.	Spencer Local Hazard Inventory
Cherry Street & cross streets	Culverted brook, just parallel (south) of Cherry Street	Entire Cherry Street neighborhood. Culvert fills, then floods homes and yards; worst area near Dale St. Resident at 18 Ash St reports culvert under street floods and stream backs up floods his yard and neighbor's yard.	Spencer Culvert Prioritization Map Resident Input
South Spencer Road	Sevenmile River tributary	At Hebert Road. Road flooding. Undersized culvert.	Spencer Local Hazard Inventory

Table 2. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Spencer

Vulnerability Point	Flooding Source	Description	Information Source
South Spencer Road	"Plourdes Pond" (swampy area); beavers	North of Tom Casey Road. Road flooding.	Spencer Local Hazard Inventory
Buck Hill Dam	Below dam's spillway	Home flooding just below dam.	Spencer Local Hazard Inventory
Chickering Road	Stiles Reservoir	Drainage improvements completed.	Spencer Local Hazard Inventory
Dufault Road		Drainage improvements completed.	Spencer Local Hazard Inventory
Thompson Pond Road & 99 Lakeshore Drive	Stormwater runoff	Berm on Thompson Pond Road is not stopping water from coming down driveway. Last storm driveway flooded. Berm has failed and requesting berm be repaired or replaced.	Spencer Culvert Prioritization Map Resident Input
Paxton Road	Stormwater runoff	Berms are old and water is going into building at #140. Property floods at #16; resident suspects blocked pipe under road, but does see anything in the way.	Spencer Culvert Prioritization Map Resident Input
30 & 31 Northwest Road	Stormwater runoff	Road flooding like never before.	Spencer Culvert Prioritization Map Resident Input
29 Woodside Road	Stormwater runoff	Runoff floods driveway.	Spencer Culvert Prioritization Map Resident Input
21 Old Farm Road	Stormwater runoff	Berm is broken by culvert drain causing a backup in driveway. Over the years plow has worn down berm and water has been backing up into driveway over time.	Spencer Culvert Prioritization Map Resident Input
13 Smithville Road	Stormwater runoff	Backed up drains causes major flooding which flows into cellar.	Spencer Culvert Prioritization Map Resident Input
58 Lincoln St	Flushing hydrants	Flushing hydrants: Received damage from water when hydrant was flushed. Took out retaining wall at his house and flooded neighbor's front yard.	Spencer Culvert Prioritization Map Resident Input
31 & 35 Donnelly Road	Stormwater runoff	Resident at #35 reports water rushing from street down driveway into basement and Flood in front of house. There used to be a berm before Donnelly Road project.	Spencer Culvert Prioritization Map Resident Input

Table 2. Documented Areas of Flooding, Erosion, or Infrastructure Damage Due to Storms – Town of Spencer

Vulnerability Point	Flooding Source	Description	Information Source
18 Adams St	Stormwater runoff	Property floods when it rains.	Spencer Culvert Prioritization Map Resident Input
GH Wilson Road	Stormwater runoff	Beaver Dam blocking culvert making road vulnerable to flooding.	Spencer Culvert Prioritization Map Resident Input
2 Marble Road	Stormwater runoff	Property floods when it rains.	Spencer Culvert Prioritization Map Resident Input
27 Chickering Road	Stormwater runoff	Runoff rushes down road into residential retaining wall. Resident would like to redirect stormwater back into the road.	Spencer Culvert Prioritization Map Resident Input
269 Charlton Road	Stormwater runoff	Drainage driven flooding of driveway.	Spencer Culvert Prioritization Map Resident Input
28 Briarcliff Lane	Stormwater runoff	Drainage driven flooding of property.	Spencer Culvert Prioritization Map Resident Input

Notes:
1. FEMA FIS – Federal Emergency Management Agency, Flood Insurance Study, Worcester County, Massachusetts, Effective July 4, 2011, Revised July 16, 2014.
2. Spencer Local Hazard Inventory – Local hazards identified by Town of Spencer as part of Central Massachusetts Regional Planning Commission (CMRPC) Hazard Mitigation Planning effort currently underway.
3. MVP CRB Workshop – Municipal Vulnerability Preparedness Program Community Resilience Building Workshop, Town of Spencer, April 7, 2018

Appendix B

Road-Stream Crossing Assessment Technical Memorandum

FUSS & O'NEILL

MEMORANDUM

TO: Project Steering Committee

FROM: Erik Mas, P.E., Julianne Busa, Ph.D.
Fuss & O'Neill, Inc.
1550 Main Street, Suite 400
Springfield, MA 01103

DATE: May 31, 2019

RE: Road-Stream Crossing Assessment
Integrated Water Infrastructure Vulnerability Assessment and Climate Resiliency Plan
MVP Action Grant – Town of Charlton & Town of Spencer

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1 Introduction

Inadequate or undersized road-stream crossings can be flooding and washout hazards and can serve as barriers to the passage of fish and other aquatic organisms. As precipitation events become more intense and less predictable as a result of climate change, inadequate or undersized road-stream crossings throughout the Town of Charlton and the Town of Spencer are expected to pose a greater threat of failure; flooding damage to homes and businesses, transportation infrastructure, and utilities; and stream channel erosion.

Fuss & O'Neill assessed road-stream crossings throughout the two towns in support of Charlton and Spencer's Integrated Water Infrastructure Vulnerability Assessment and Climate Resiliency Plan, a project which was funded through the inaugural round of the Commonwealth's Municipal Vulnerability Preparedness (MVP) Action Grant funding. The primary goal of the overall project is to increase resilience to flooding and flood-related impacts throughout the Towns. To that end, the project systematically assessed road-stream crossings Town-wide in both communities to identify vulnerabilities and rank high priority culvert/bridge replacement projects that would address flood vulnerability, reduce flooding impacts, and increase stream continuity for aquatic organism passage.

The assessments consisted of field surveys of individual stream crossings using established road-stream crossing assessment protocols, followed by analysis of the field data to assign vulnerability ratings to each crossing based on multiple factors including hydraulic capacity, structural condition, geomorphic risk, aquatic organism passage, transportation and emergency services, other flooding impacts, and climate change considerations. The vulnerability ratings are used to prioritize structures for upgrade or replacement. The results of the stream crossing assessments will inform the selection of infrastructure and natural system solutions to increase flood resilience in both communities.

This memorandum summarizes the methods and results of the road-stream crossing field surveys and vulnerability assessment. Recommendations are presented based on field observations and the vulnerability assessment and prioritization process.

2 Stream Crossing Field Surveys

2.1 Selection of Crossings

Road-stream crossings to be included in the assessment were initially identified based on review of aerial imagery, flood mapping, and other local, county, or state-wide data layers. The Project Steering Committee reviewed these maps and provided additional information on locations of known culvert/bridge infrastructure where flooding was already a concern. The project sought to assess all crossings Town-wide which could reasonably and safely be assessed. Note that there are 32 mapped crossings on the Mass Pike (Route 90) and 14 mapped crossings on State Route 20 that could not be accessed for assessment.

241 road-stream crossings throughout the two towns were ultimately assessed via field surveys and desktop vulnerability assessments (132 crossings in Charlton and 109 crossings in Spencer). As shown in Figure 1, the crossings span seven watersheds. The locations of the selected crossings are shown on the watershed map in Figure 1. Summary information on each crossing is provided in Appendix B—Table 1.

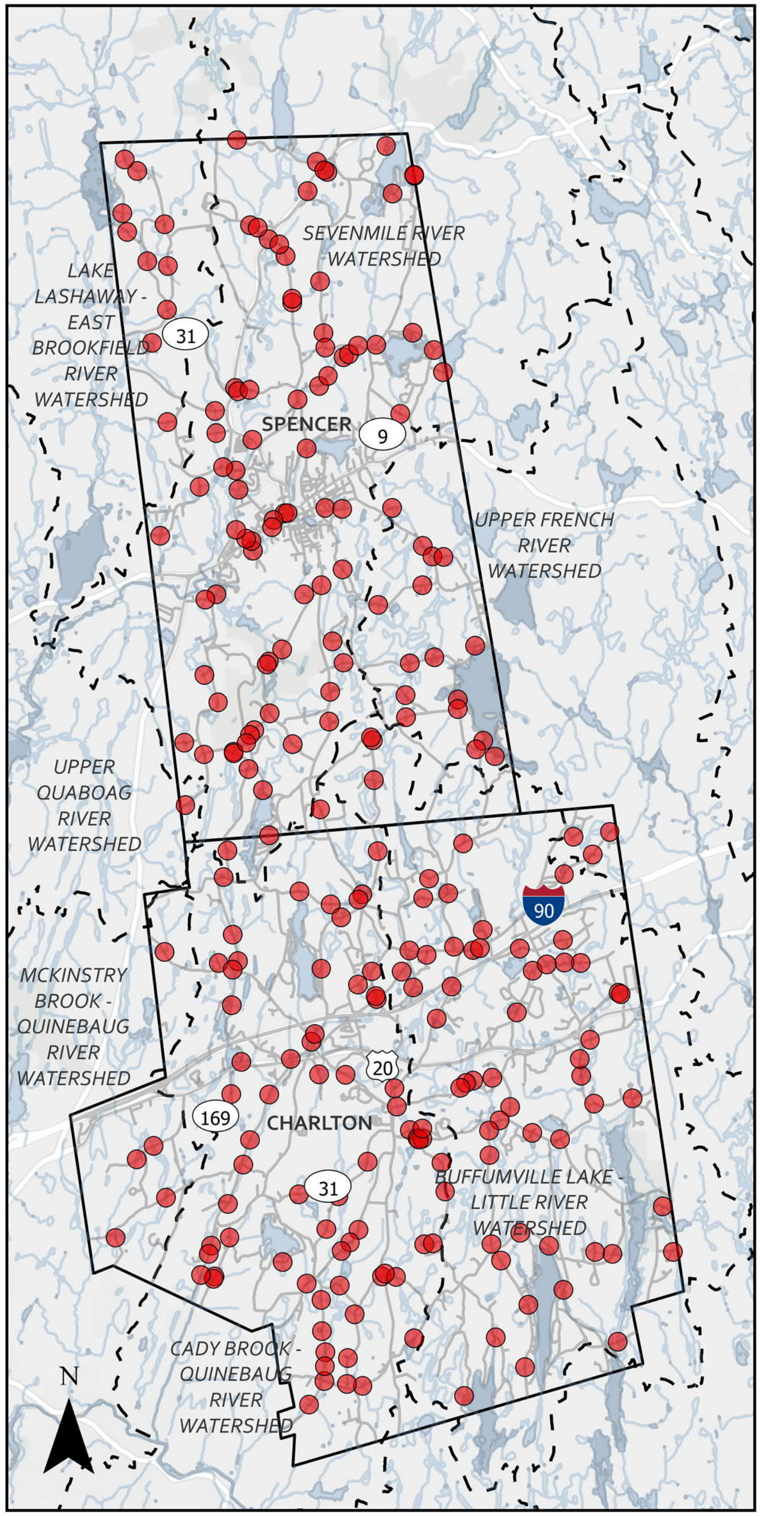


Figure 1. Road-stream crossings selected for assessment in the Town of Charlton and the Town of Spencer. Watershed boundaries are indicated by dotted lines.

2.2 Field Data Collection

Field surveys of the selected crossings were conducted between October 16th and November 15th, 2018 using road-stream crossing assessment procedures and field data collection forms adapted from the North Atlantic Aquatic Connectivity Collaborative (NAACC) and similar standardized assessment protocols used in the northeastern U.S. In addition to the 2016 NAACC stream crossing survey protocol for assessing aquatic connectivity, the road-stream crossing survey methods used for this project also incorporated structural condition assessment protocols from the 2017 NAACC Culvert Condition Assessment Manual and collection of other field data for evaluating geomorphic vulnerability, hydraulic capacity, and potential flooding impacts to infrastructure and public services. Digital photographs were also taken at each crossing. A blank copy of the field data collection form is provided in Appendix A.

The crossing surveys were performed by a two-person field crew consisting of water resources and wetland scientists. The field crew was led by a NAACC-Certified Lead Observer; additional training was also provided for all field personnel prior to the field work. Digital field data collection methods were used to complete the crossing surveys, using a GPS-enabled tablet with a pre-loaded digital version of the field form and aerial imagery for the project locations. Field data for the project are saved and managed using an ArcGIS database and web application (Figure 2). Following the stream crossing surveys, field data were checked for quality control purposes.

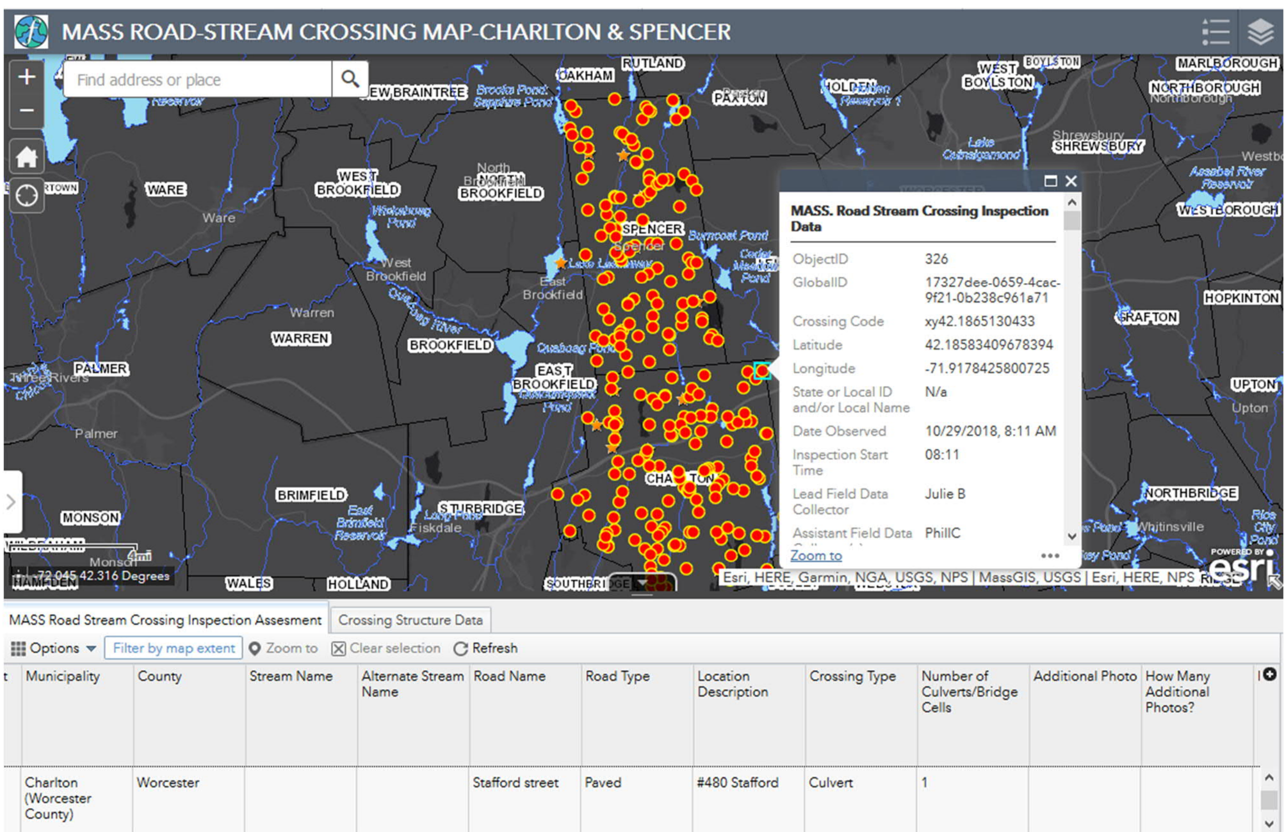


Figure 2. ArcGIS web application for Charlton and Spencer stream crossing survey data.

2.3 Crossing Survey Findings Summary

Appendix B summarizes key field data and findings of the road-stream crossing surveys for the Town of Charlton and the Town of Spencer.

The following issues were observed at the surveyed stream crossings:

- Poor Structural Condition: Many of the crossings were observed to be in poor condition and in need of significant repairs or replacement. Significant erosion of the crossing embankment and unstable or deteriorating headwalls or wingwalls were common at many of these crossings. Corrugated metal pipes with rusted out bottoms were also relatively common throughout the Towns.

Figure 3. Examples of crossing structures in poor structural condition observed at various locations during field assessments. Left: Degraded concrete armoring; Center: rusted out pipe inverts; Right: collapsed headwall at outlet.

- Flow Constriction: All but twenty-two of the assessed crossings, including the assessed culverts and bridges, are significantly narrower than the bankfull width of the stream channel and therefore appear to constrict flood flows. 156 of the crossings were rated as severely constricted, indicating that the bankfull width of the stream channel was at least twice as wide as the structure opening(s). The hydraulic capacities of many of the crossings in the watershed are limited due to undersized crossing structures and/or significant accumulation of sediment at some locations.
- Physical Barriers: 55% of the crossings serve as moderate to severe barriers to aquatic organism passage. Several structures have cascading or freefalling outlets with drops of up to ten feet. Most structures do not have substrates that match the streambed, creating a discontinuity for organisms trying to pass through the crossing.
- Channel Erosion: Varying degrees of stream channel erosion were observed in the reaches immediately upstream and/or downstream of the assessed crossings. Efforts to repair recent channel erosion through channel grading and bank stabilization were evident at several of the surveyed locations.
- Sediment Deposition: Substantial sediment deposition was observed at 94 crossings throughout the Towns. At these locations, sediment deposits were noted to have depths at least half the height of the stream banks. Such sediment deposition can reduce flow conveyance capacity, increase the potential for blockage or clogging during higher flows, and potentially restrict aquatic passage during low-flow conditions.

3 Vulnerability Assessment and Prioritization

Using data from the stream crossing surveys and available GIS data, each of the assessed crossings was assessed for vulnerability to flooding and associated impacts relative to hydraulic capacity, structural condition, geomorphic conditions, aquatic organism passage, transportation services, land use, and climate change considerations (Appendix C). The vulnerability and impact ratings were then combined to generate an overall rating, which was used to assign a priority to each crossing for potential upgrade or replacement (Appendix C).

3.1 Assessment Method

The following individual assessments were performed for each stream crossing:

- Existing and Projected Future Streamflow: Estimated existing and future (climate change scenario) peak discharge for common recurrence intervals using regional regression equations developed by USGS for estimating peak flows at ungaged locations (i.e., StreamStats) or drainage area ratios for crossing locations where regional regression equations are unreliable. Flood flows under future climate change were estimated using a design flow multiplier of 1.2, representing a 20% increase in rainfall intensity above current conditions to account for anticipated increases in design rainfall intensities associated with future climate change projections. The recommended 20% increase in design rainfall intensity is consistent with climate change projections for extreme precipitation under a medium to high emissions scenario and a 50- to 100-year planning horizon, based on the typical design life (50 years) of most storm drainage infrastructure, and the useful life, which is typically 50-100 years for stormwater infrastructure. It should be noted that design life is different from useful life, which is typically longer than the design life and more accurately represents the extended service life of infrastructure, assuming regular maintenance.
- Hydraulic Capacity: Estimated the hydraulic capacity of each road-stream crossing using standard Federal Highway Administration culvert/bridge hydraulic calculation methods following FHWA Hydraulic Design Series Number 5 (HDS-5). Bentley CulvertMaster, which employs HDS-5 methods, was used for the analysis. Hydraulic capacity was determined for a selected headwater depth, which represents that depth at which the crossing is at risk of structural failure or the roadway is at risk of overtopping, depending on crossing type and material. Manning's Equation for uniform open channel flow was used to estimate the crossing hydraulic capacity for lager structures (bridges) or where the cross-sectional area could not be approximated with CulvertMaster. A capacity ratio (defined as the ratio of estimated hydraulic capacity to the estimated peak discharge for a specified return interval) was calculated for each crossing for existing and projected future peak streamflow.
- Structural Condition: Assigned condition ratings and scores based on visual observation of the structural condition of the crossing inlet, outlet, and barrel adapted from the latest version of the NAACC Culvert Condition Assessment Manual, which was developed with input from state transportation departments throughout the Northeast and other stakeholders. The NAACC condition assessment methodology is designed as a rapid assessment tool for use by trained observers for purposes of flagging crossings that should be examined more closely for potential structural deficiencies.

- Geomorphic Impacts: Assessed the potential for crossing structures to impact geomorphic processes that might, in turn, threaten the structure itself and other adjacent infrastructure. The assessment procedure distinguishes between crossings that are: 1) not prone to and have not experienced geomorphic adjustments; 2) prone to but have not experienced geomorphic adjustments; and 3) prone to and have experienced geomorphic adjustments. The approach rates the relative likelihood that impacts could occur and the type and severity of impacts that have already occurred. Factors that were considered include stream alignment, bankfull width, degree of constriction, significant breaks in valley slope, bank erosion, sediment deposition, structure and channel slope, stream bed material, and other geomorphic parameters.
- Aquatic Organism Passage: Assessed aquatic organism passage (AOP) using the latest NAACC protocols and rating system for assessing stream continuity. The method was adapted from the NAACC Numeric Scoring System for AOP, which was developed with input from multiple experts in aquatic passability. The NAACC Numeric Scoring System methodology is designed as a quantitative but rapid assessment tool for use by trained observers. The assessment is not species-specific, but rather seeks to evaluate passability for the full range of aquatic organisms likely to be found in rivers and streams.
- Impacts to Transportation Services: Evaluated the potential disruption of transportation services resulting from single crossing failures by considering the functional classification of the roadway (i.e., level of travel mobility and access to property that it provides). Disruption of transportation services is assumed to occur if the crossing is either overtopped or washed away by flooding, as either failure mode would prohibit the use of the road-stream crossing by traffic.
- Other Potential Flooding Impacts: Assessed the potential impact to existing development, infrastructure, and land use upstream and downstream of each stream crossing in the event of failure of the crossing. A potential impact area was approximated for each crossing, having a width defined by buffering the stream centerline by a distance equal to two times the bankfull width, and a length defined as 0.5 miles upstream and downstream of the crossing. Flooding vulnerability was quantified based on the percentage of developed land cover, using 0.5 meter resolution land cover data from the Massachusetts statewide Land Use (2005) data layer, and the presence of upstream or downstream crossings within the impact area, as well as any infrastructure (gas, sewer, water, etc.) observed to be attached to or located within the crossing structure.

3.2 Prioritization Method

The crossing structures were assigned a relative priority for upgrade or replacement based on the results of the individual assessments and consideration of failure risk. Failure risk is defined as the product of the probability of failure of a crossing (i.e., vulnerability) and the potential consequences of failure (i.e., impacts). A crossing may be at risk if the probability of failure is high, if the consequences of failure are high, or both. An overall priority score was calculated based on the combined hydraulic risk (existing and future climate change), geomorphic risk, structural risk, and aquatic organism passability of each crossing.

The overall failure risk for a crossing (represented by the Crossing Risk Score) is dictated by the highest (i.e., worst-case) level of risk, which is calculated as the maximum of the hydraulic risk and future hydraulic risk scores, geomorphic risk score, and structural risk score. The potential ecological benefit of removing an existing barrier to aquatic passage is also an important consideration in the crossing prioritization process. The additional habitat value accessed after a crossing replacement depends on both the quality and the extent of aquatic habitat that is reconnected as a result of replacing the existing crossing with a structure that provides for improved aquatic passage. Aquatic passage benefit scores were assigned to each crossing based on the concept of Index of Ecological Integrity (IEI). IEI scores were derived using the Critical Linkages methodology developed by the Landscape Ecology Lab at UMass Amherst as part of the Conservation Assessment and Prioritization System (CAPS) program.

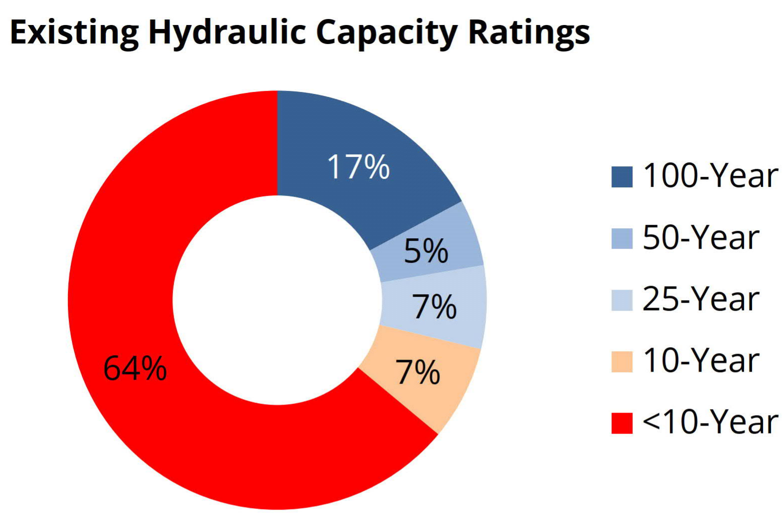
A Crossing Priority Score was calculated for each crossing by combining the Crossing Risk Score with the aquatic passage benefit score. (The two scores are combined by adding the maximum of the two scores to the average of the two scores. This approach ensures that if there is a very high score for one factor, it is preserved. It does however prioritize those crossings that rate highly for both factors.) The Crossing Priority Score is then re-scaled or normalized to a range from 0 to 1 for ease of interpretation. It is important to note that the crossing priority scores should only be used for relative comparisons between crossings.

3.3 Assessment and Prioritization Results

Table 1 summarizes the hydraulic risk (existing and future), geomorphic risk, structural risk, and aquatic organism passability scores, as well as the relative priority score (normalized on a scale of 0 to 1) for each of the highest priority crossings located in the two Towns. The detailed road-stream crossing assessment and prioritization worksheets and scores are provided in Appendix B.

Hydraulic Risk

64% of the crossings assessed are hydraulically undersized under existing precipitation conditions, having insufficient capacity to convey the 10-year peak flow (Figure 4). Another 7% of crossings are hydraulically undersized relative to the 25-year return interval flow (Figure 4). 17% of crossings were found to be sized such that they could pass the 100-year return interval flow under existing conditions (these include larger bridges, as well as some smaller



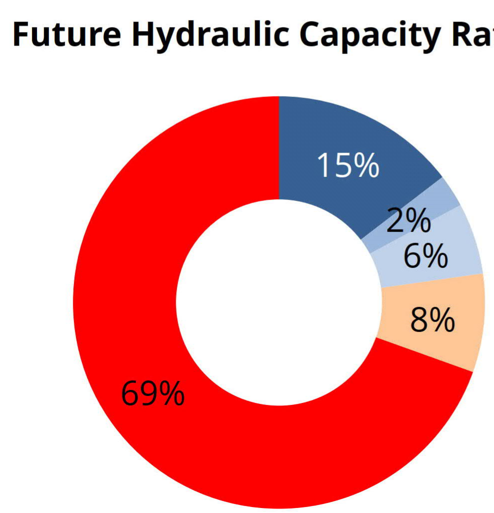


Figure 4. Distribution of hydraulic capacity ratings across all assessed crossings, for both existing conditions and expected future precipitation conditions under climate change.

structures where peak flows are also low as a result of a smaller watershed area feeding into the crossing). Under future expected flows, assuming an increase in peak flows of 20%, 69% of crossings are expected to be undersized for the 10-year peak flow, 8% are expected to be undersized for the 25-year return interval flow, and only 15% are expected to be able to pass the 100-year return interval flow.

These percentages are for all crossings taken together, but hydraulic capacity ratings differ by structure type (Figure 5). Bridges, due to their less constricted openings, are generally sized to accommodate larger flows. Round culverts, on the other hand, often tend to be undersized, with many of the undersized structures throughout the two Towns falling into this category. Box culverts in the two

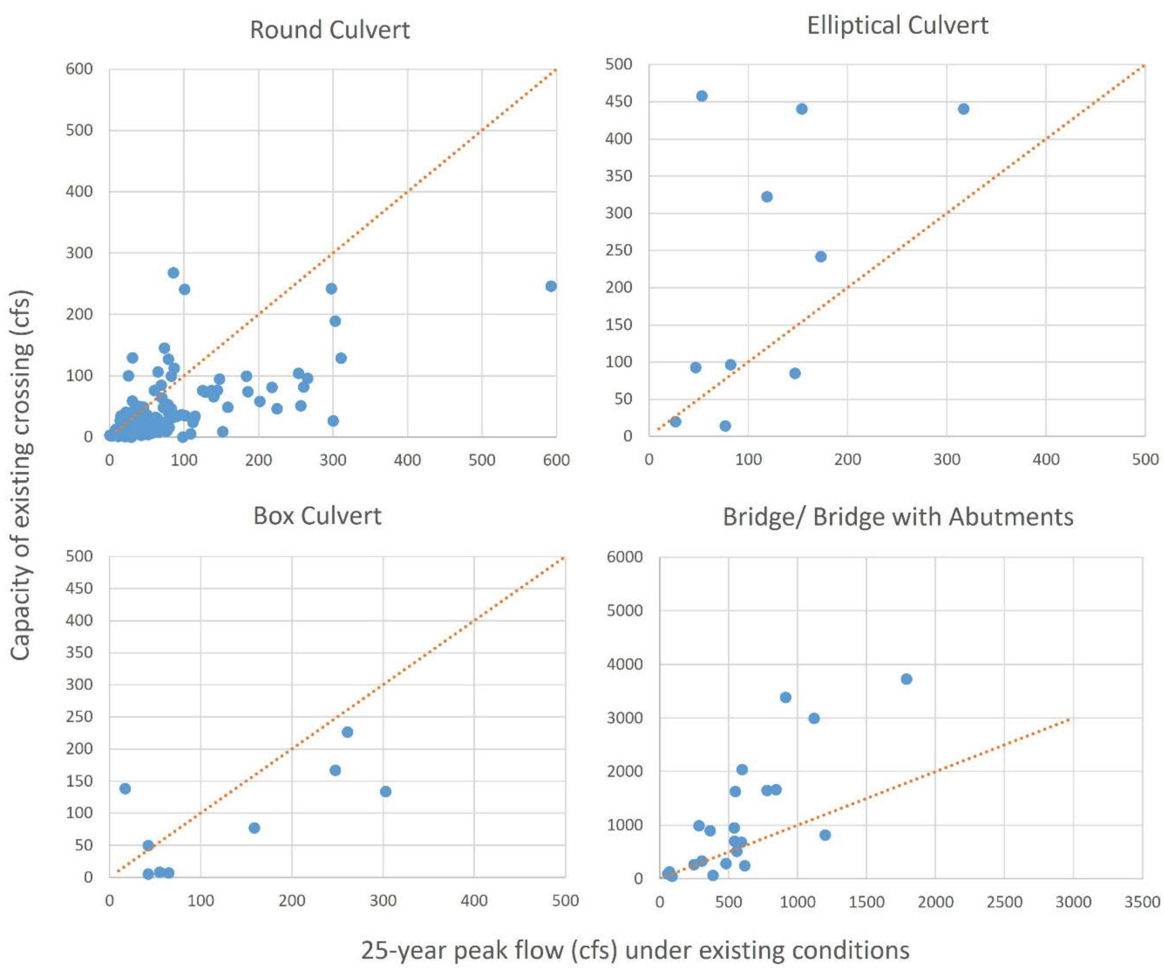


Figure 5. Capacity of existing crossings relative to the existing 25-year return interval flood, broken down by structure type. The dotted line in each panel represents the point at which capacity is matched to peak flows at a 1:1 ratio. Points above the line are sized with excess capacity for the 25-year return interval peak flow; points below the line have insufficient capacity to pass the 25-year return interval peak flow.

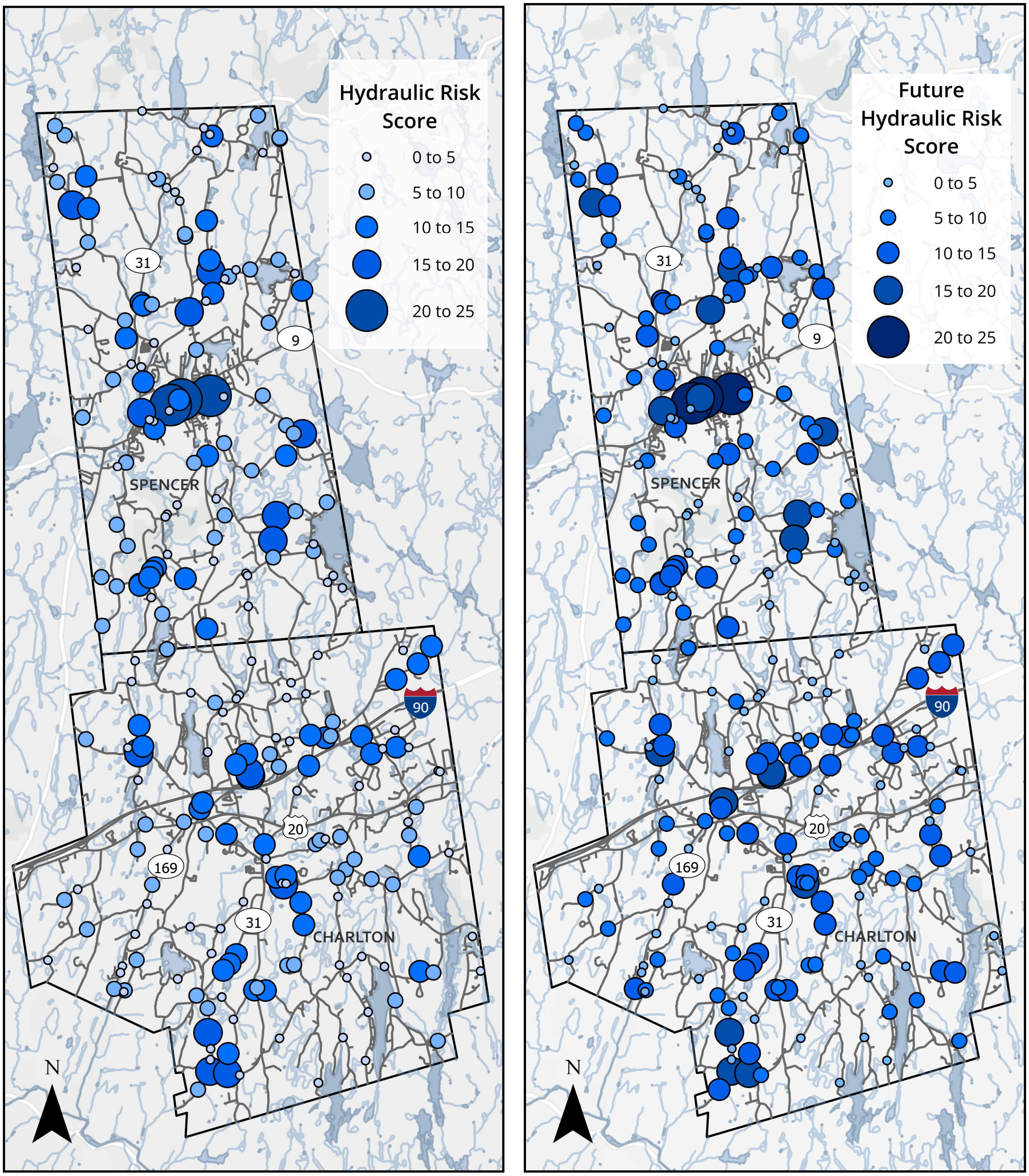


Figure 6. Spatial distribution of hydraulic risk scores for all assessed crossings under existing (left) and future (right) precipitation conditions.

Geomorphic Risk

Approximately 33% of all assessed crossings were rated as having severe or significant geomorphic risk, taking into account both observed geomorphic impacts and potential geomorphic impacts (Figure 7). An additional 49% were rated as having moderate geomorphic risk. The remaining 18% of crossings were found to have low risk/unlikely geomorphic impacts. Crossings with the highest geomorphic risk include crossings on Mill Street, May Street, Gold Nugget Road, Marble Road, and Wire Village Road in Spencer and Route 169/Southbridge Road and Stafford Street in Charlton (Figure 8). Most of these structures of highest concern are clustered in the Sevenmile River or Cady Brook-Quinebaug River watersheds.

Structural Risk

46% of assessed crossings were rated as critical relative to structural condition, and 52% were rated as either good or satisfactory (Figure 7). Of the ten crossings that rated highest for structural risk based on structural condition and potential for flooding impacts (with scores of 20 to 25 out of 25) five are also among the top priority crossings overall (Table 1). The crossings with the highest structural condition scores are clustered in the Spencer town center area (Figure 8).

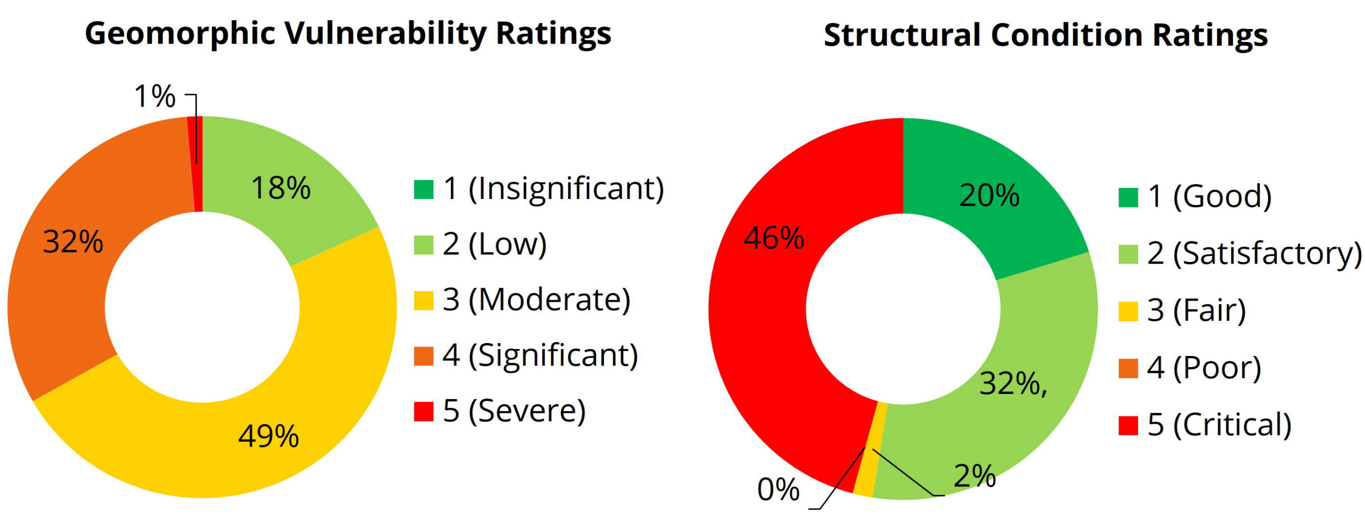


Figure 7. Distribution of geomorphic vulnerability and structural condition ratings across all assessed crossings.

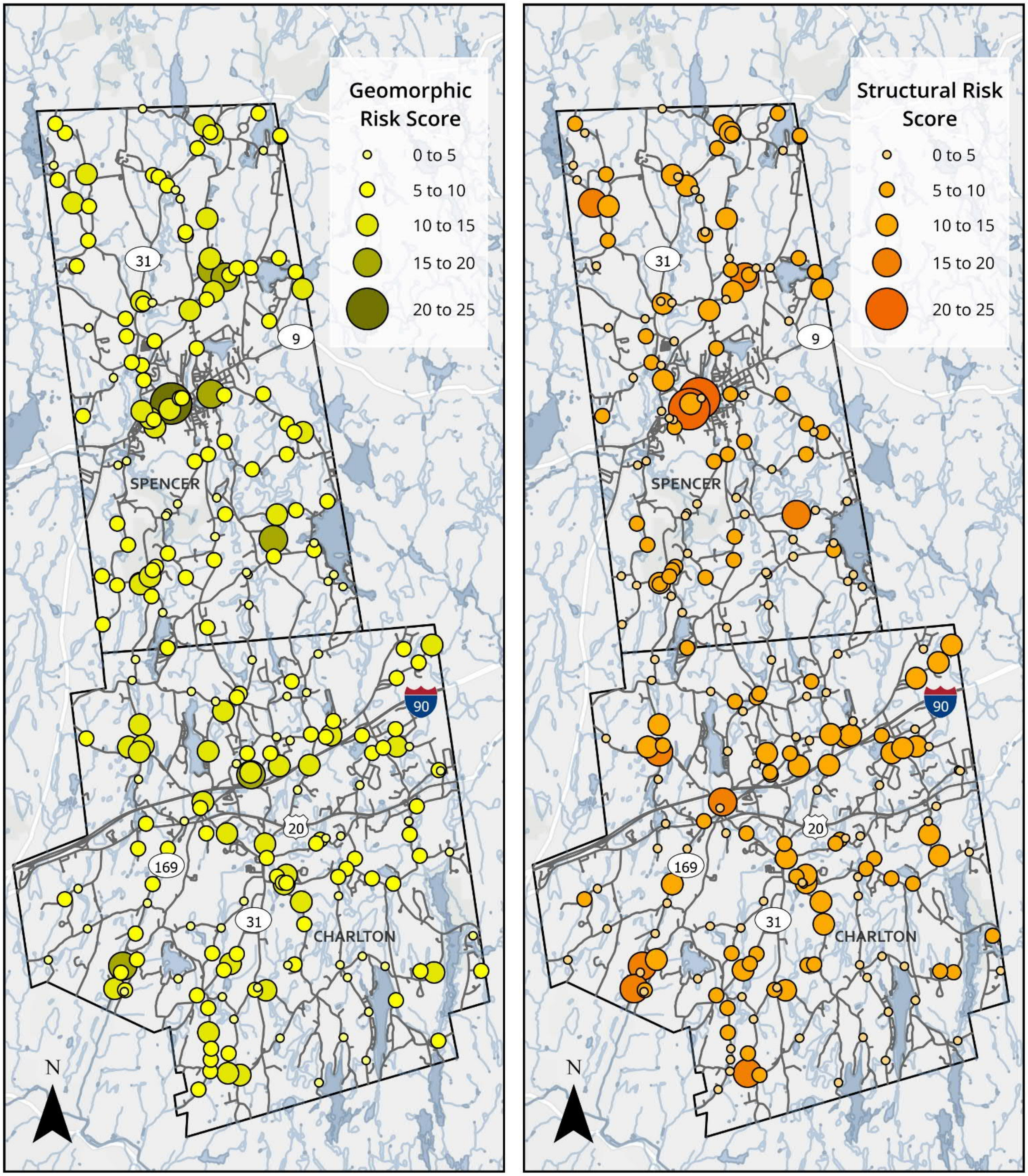


Figure 8. Spatial distribution of geomorphic risk scores (left) and structural condition scores (right) for all assessed crossings.

Aquatic Organism Passage

Approximately 55% of structures are considered moderate or worse barriers to aquatic organism passage, but only 15% of structures are considered to act as significant barriers (Figure 9). 19% are considered to provide full aquatic passage. Among the 34 crossings with the highest potential AOP benefit scores—that is, crossings which are barriers to aquatic organism passage but which are also at locations where improved passage would have the greatest benefit—25 were also scored as high priority overall. The majority of the crossings with the highest AOP benefit scores are evenly split between the Sevenmile River, Buffumville Lake-Little River, and Cady Brook-Quinebaug River watersheds (Figure 10).

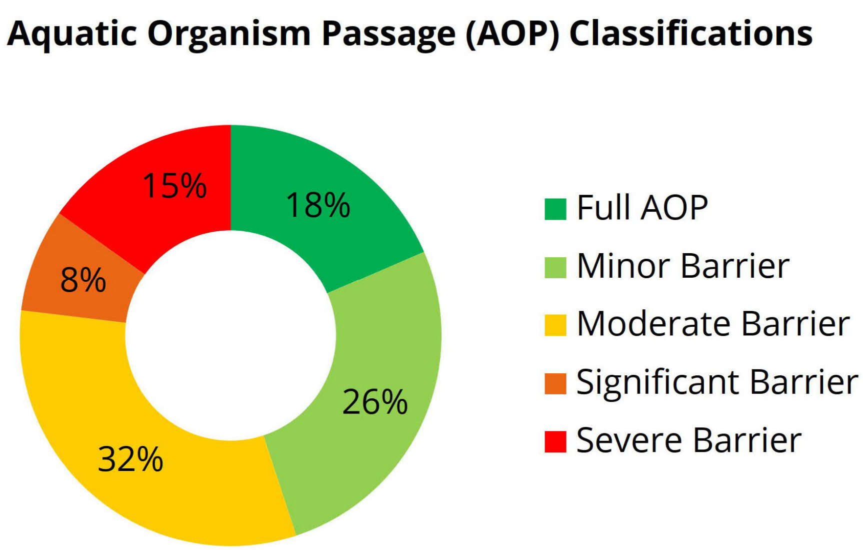


Figure 9. Distribution of aquatic organism passage classifications across all assessed crossings.

Potential Flood Impacts

Because impacts to transportation services were calculated as a function of road classification, the crossings with the highest potential for transportation disruption were found to occur on state roadways, with the highest impact crossings located on Route 169/Southbridge Road and Route 9. The sites with the highest potential for flooding impacts were located in densely developed areas, particularly the Spencer town center area. High impact scores related to potential flooding were largely clustered within the Sevenmile River, Cady Brook-Quinebaug River, and Upper French River watersheds. Crossings in the Spencer town center area were the highest ranked overall for potential impacts (Figure 11).

Prioritization

The seven crossings with the highest overall scaled crossing priority values are all located within the Sevenmile River watershed, in the Town of Spencer. The Elm Street crossing of an unnamed tributary to the Sevenmile River and the Wire Village Road crossing of an unnamed tributary to Turkey Hill Brook (xy42267367198603) were the two highest priority crossings overall, with the highest potential for impacts due to flooding or service disruptions and high risks associated with both current and future hydraulic capacity, and in the case of the Wire Village road crossing, structural risk. Both of the top priority crossings are also among the highest priorities for aquatic organism passage. Downstream of

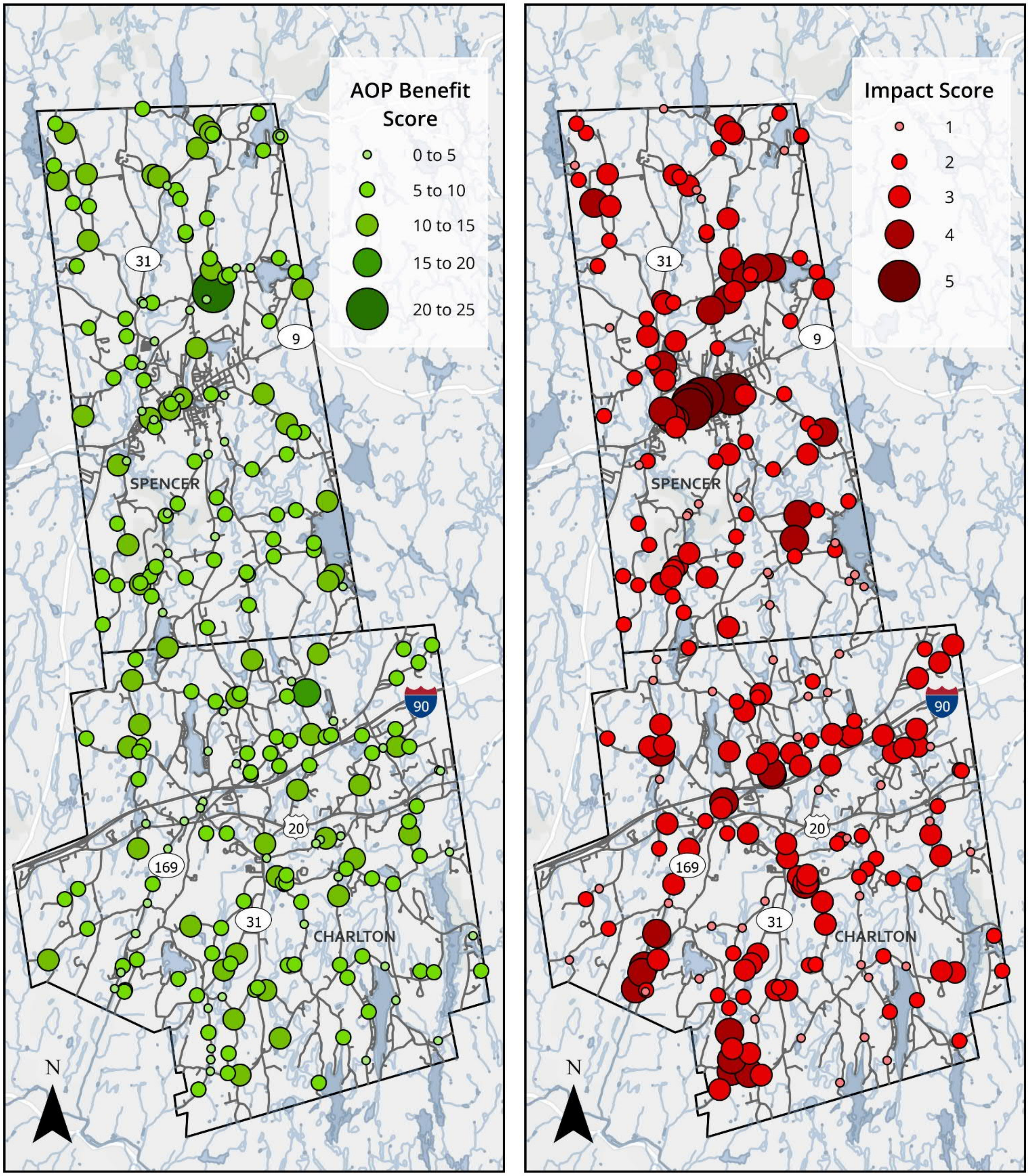


Figure 10. Spatial distribution of aquatic organism passage benefit (left) and impact scores (right) for all assessed crossings.

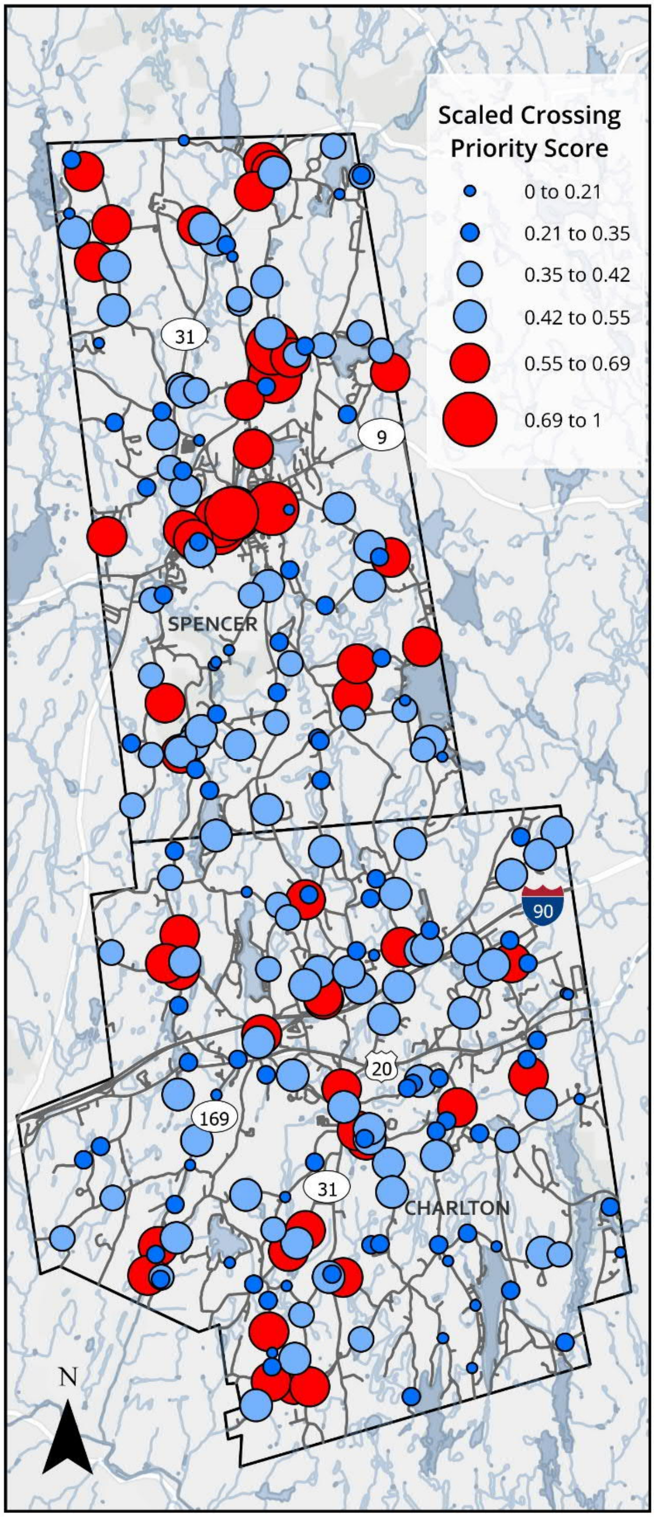


Figure 11. Spatial distribution of scaled crossing priority scores for all assessed crossings. Red dots indicate high priority crossings; light blue dots indicate medium priority crossings, and dark blue dots indicates low priority crossings.

the Elm Street crossing, three additional crossings of the same tributary at Water Street, Mill Street, and Valley Street are the third, fourth, and sixth highest priority crossings, respectively. Crossings of unnamed streams at May Street and Gold Nugget Road are also among the top seven crossings (Table 1, Figures 11, 12).

The next highest ranked cluster of crossings consists of 8 crossings all receiving a score of 0.69. These crossings are spread between the Sevenmile River, Cady Brook-Quinebaug River, and Upper French River watersheds, and split between Charlton and Spencer (Table 1, Figures 11, 12).

Table 1. Top-ranked high priority crossings: road-stream crossing vulnerability assessment and prioritization results summary

Road Name	Town	HUC 12 Watershed Name	Impact Score	Existing Hydraulic Risk Score	Future Hydraulic Risk Score	Geomorphic Risk Score	Structural Risk Score	AOP Benefit Score	Crossing Risk Score	Crossing Priority Value	Scaled Crossing Priority	Relative Priority Rating
Wire Village Rd	Spencer	Sevenmile River	3	15	15	12	15	25	15	45	0.9	High
Elm St	Spencer	Sevenmile River	5	25	25	10	5	15	25	45	0.9	High
Water St	Spencer	Sevenmile River	5	0	0	15	25	12	25	43.5	0.87	High
Mill St	Spencer	Sevenmile River	5	25	25	25	15	9	25	42	0.84	High
May St	Spencer	Sevenmile River	5	25	25	20	10	6	25	40.5	0.81	High
Valley St	Spencer	Sevenmile River	5	15	20	10	25	3	25	39	0.78	High
Gold Nugget Rd	Spencer	Sevenmile River	4	20	20	16	8	12	20	36	0.72	High
East Baylies Rd	Charlton	Cady Brook-Quinebaug R.	4	20	20	12	20	9	20	34.5	0.69	High
Stafford St	Charlton	Cady Brook-Quinebaug R.	4	20	20	16	8	9	20	34.5	0.69	High
Blood Rd	Charlton	Cady Brook-Quinebaug R.	4	20	20	12	8	9	20	34.5	0.69	High
Center Depot Rd	Charlton	Cady Brook-Quinebaug R.	4	20	20	12	8	9	20	34.5	0.69	High
Freeman Rd	Charlton	Cady Brook-Quinebaug R.	4	16	20	12	4	9	20	34.5	0.69	High
Brooks Pond Rd	Spencer	Lake Lashaway-E. Brookfield	4	20	20	12	20	9	20	34.5	0.69	High
Wire Village Rd	Spencer	Sevenmile River	4	4	8	16	20	9	20	34.5	0.69	High
Greenville St	Spencer	Upper French R.	4	20	20	12	8	9	20	34.5	0.69	High
Marble Rd	Spencer	Upper French R.	4	20	20	16	4	9	20	34.5	0.69	High

4 Recommendations

Specific recommendations were developed for the top priority stream crossings that were evaluated as part of this assessment (Table 1). These planning-level recommendations are intended to enhance the resilience of the stream crossings and river system by withstanding extreme flood events, providing for the passage of debris during floods, and providing for passage of aquatic organisms under normal flow conditions. At several of the crossings, we also recommend channel or floodplain restoration in upstream or downstream areas along with the proposed crossing upgrades to enhance flood resilience, water quality, and aquatic habitat using a combination of natural and infrastructure-based approaches.

Planning-level cost estimates will be provided for each of the recommendations in the final report. Estimated costs will be presented as screening-level cost ranges for the purpose of comparing and prioritizing various alternatives and to help select a preferred alternative based on relative project benefits and costs. The planning-level cost ranges will include estimates of the anticipated design and construction costs. Design and construction costs are based on costs of recent similar stream crossing replacement projects in the northeastern U.S.

The following sections provide a summary of the existing issues, recommendations, and screening-level cost ranges for Charlton and Spencer's top priority stream crossings where upgrades or replacement are recommended.

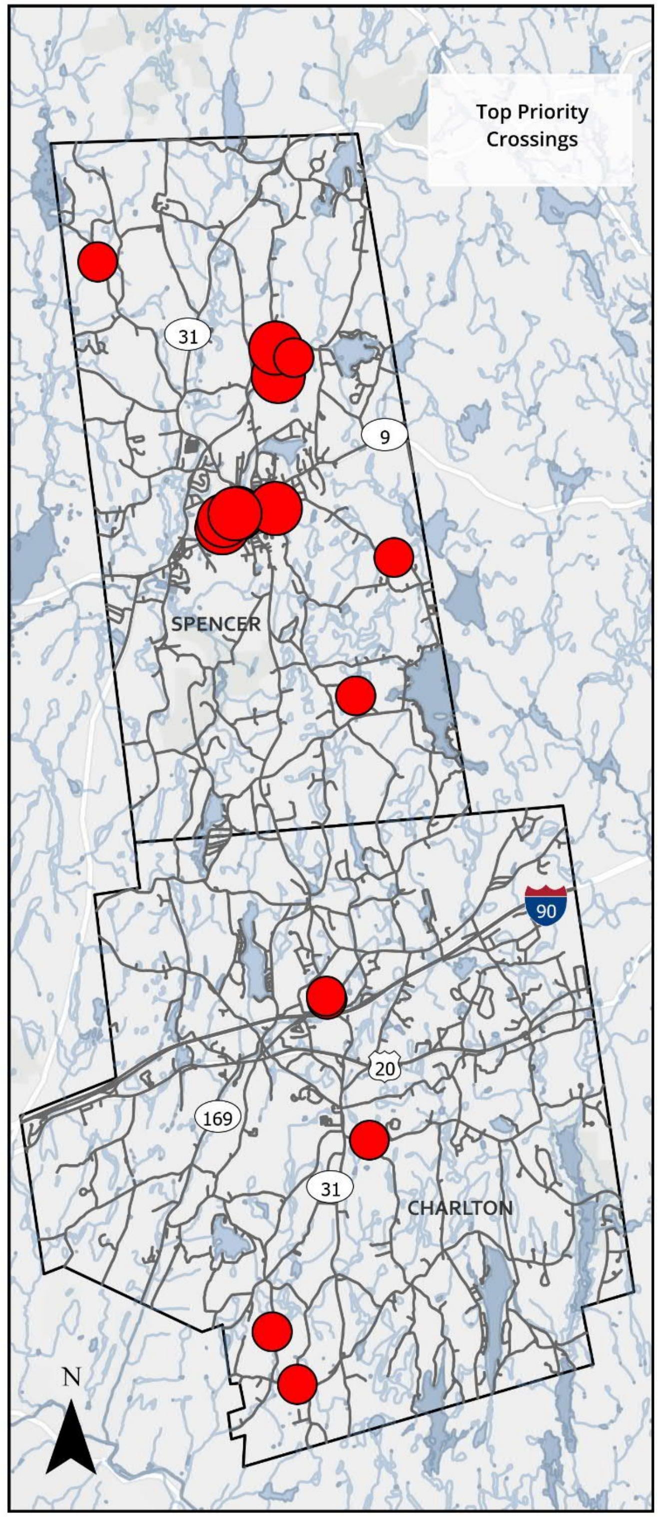


Figure 12. Locations of top sixteen highest-ranked priority crossings. Larger dots indicate higher priority scores.

4.1 Top Priority Crossings—Town of Charlton

4.1.1 East Baylies Road

Site Description

East Baylies Road crosses an unnamed stream just north of Saundersdale Road. The crossing consists of multiple materials; the inlet is a stone box culvert approximately 3 feet wide and 2.5 feet high, but the outlet is a single corrugated metal pipe of approximately 2 feet in diameter (Figure 13). Both the inlet and outlet are significantly narrower than the stream's approximately 11-foot bankfull width, resulting in severe constriction. There is a drop at the inlet due to a blockage that was rated as critical, and the outlet pipe is badly deteriorated and was rated as critical for invert condition, seam condition, crushing, and structural integrity. The crossing is sized to pass the 10-year peak flow, but is undersized for all other return intervals and for future climate conditions.

Figure 13. View of existing crossing outlet taken during field assessment on October 16, 2018.

Proposed Concept

Replace the existing undersized culvert with a 14-foot wide embedded box culvert to accommodate the 1.2 times bankfull width design standard of the Massachusetts River and Stream Crossing Standards. Reconstruct stream banks at the crossing to match the existing stream channel up and downstream of the crossing.

- Provide increased hydraulic capacity to reduce flooding risk
- Improve hydraulic flow through the culvert by replacing the structure with one of uniform shape and material
- Reduce potential for blockages and accumulated debris at the undersized inlet

4.1.2 Stafford Street

Site Description

Figure 14. View of existing crossing outlet taken during field assessment on October 29, 2018.

Stafford Street crosses an unnamed stream just southwest of the intersection with Center Depot Road. The crossing consists of a single, 89-foot long, corrugated metal pipe of approximately 2.5 feet in diameter (Figure 14). Both the inlet and outlet are significantly narrower than the stream's approximately 6-foot bankfull width, resulting in severe constriction. The constriction of the stream has led to the development of a large scour pool at the outlet. There is a freefall condition at the structure outlet, with a drop of 0.6 feet from the pipe to the stream bottom. The structure is in relatively good condition, but